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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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THE STORAGE OF PETROLEUM.

THE storage of petroleum in this country, though for obvious reasons it will never reach the proportions it has attained in America, will be on a continually increasing scale in consequence of the ever-widening applications of the oil in industry and commerce and the recognition of its value as a source of power. Oil tanks and reservoirs will therefore increase in both size and number. The construction of these on economic lines, the prevention of the loss of the more volatile oils from evaporation, the reduction of waste from seepage and other causes, the provision of safety from ignition, all present problems that have received much attention in the United States, and the experience gained is too valuable to be neglected. The main results that have been achieved, with the plans recommended for adoption, have been collected in an exhaustive report* issued by the Bureau of Mines, in which are given not only the general principles that govern the whole problem of oil storage, but minute details concerning the means of constructing suitable holders. These latter are accompanied by precise specifications and plans, but it will be sufficient in the present article to call attention to the system generally.

Storage has grown in the States to huge dimensions. The unit of measurement may be regarded as the "tank," which has a capacity varying from 37,000 to 55,000 barrels. The latter is the more usual size, and the form generally adopted is that of a cylinder, with a diameter of about 114 ft. and a height of 30 ft. These tanks are grouped into "storage farms," the larger of which are sufficiently extensive to be able to accommodate more than 24,000,000 barrels. In such a farm, the tanks will be so arranged that a distance of some 400 ft. separates the outward periphery of each cylinder from its nearest neighbour. Each tank is then surrounded by a levee of sufficient height to hold the entire content of the tank (see Fig. 1). These levees, or artificial banks, are circular in construction and may again be enclosed in a second protecting rectangular levee, built equidistantly between the tanks, so that the whole area is divided like a chess-board, the tanks being at the centre of each square. The object of this arrangement is isolation with protection from fire. Should the contents of any one tank ignite, the fire will not be carried to the neighbouring tanks, and if the levees are properly constructed the whole contents of a tank may be burnt out without injury to its neighbours. Partly or wholly buried tanks underground is a common practice among some refiners that has been followed in this country. Secrecy as well as safety has probably dictated this course, but under normal circumstances the practice is not to be recommended. The ultimate economy is questionable, as depreciation from soil corrosion may be rapid, and leakage, unless it be on a large scale, is difficult to detect and expensive to repair. When tanks grow into reservoirs, capable of containing a million barrels, it is not practical to make the empounding area of a surrounding levee of sufficient size to hold the entire contents of a reservoir. But the protection afforded by a levee is so great, that it is the practice to construct these barriers between reservoirs, a practice that is commended by the official advisers of the Bureau.

The material of the tank should be steel, and only when the dimensions become so large that steel construction is impractical should recourse be had to concrete lined reservoirs, that have proved suitable for some grades of oil. When these are well constructed the loss from seepage is as small as in metal tanks, and in either case is negligible. If unlined earthen reservoirs are used, the waste from leakage may be serious but this form is never likely to be needed in this country. In America such reservoirs are regarded only as emergency containers, to hold the oil from rapidly flowing wells. Apart from the roofing, which will be considered later, the life of the concrete-lined reservoir is undetermined. This form has not been in use long enough to furnish a satisfactory estimate, but the steel tank as constructed to day, even when judiciously planned and carefully maintained, is not expected to last beyond 35 or 40 years. Mr. Bowie, from personal examination of tanks that have been in use from 20 to 25 years, is able to assert that the outer shell appears to be in perfect condition. One tank that had been in use for 35 years is of especial interest. The plates were of wrought-iron and much lighter than would be used now. The rivet spacing was also greater than modern practice approves, and consequently the factor of safety was lower than is now recommended. From motives of prudence the tank is used to only about two-thirds of its capacity, and the shell so far as it could be seen was found to be sound and in good condition.

FIG. 1. TANKS IN COURSE OF CONSTRUCTION.

FIG. 2. SHOWING GRADE STAKES TO OBTAIN TRUE LEVEL.

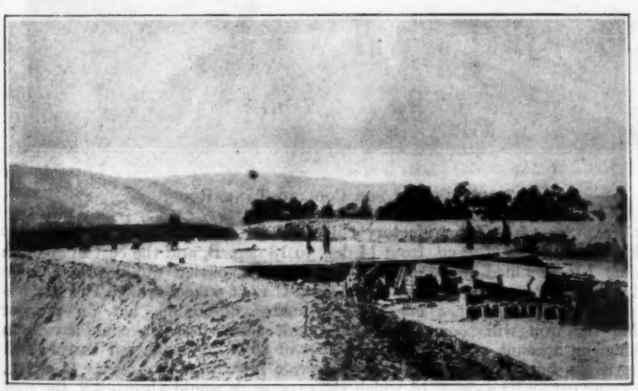

FIG. 3. SHOWING SITE FOR TANK WITH LEVELLED SAND.

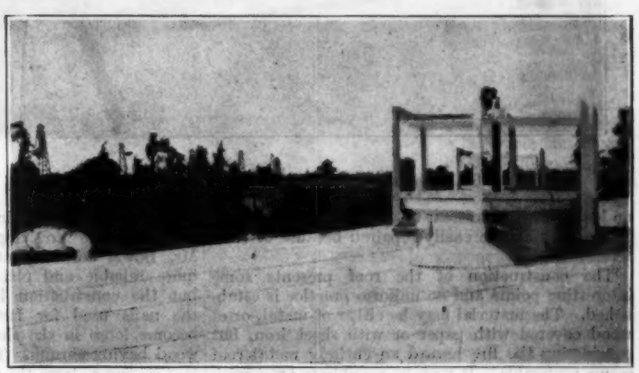

FIG. 4. EXPLOSION DOOR AND VACUUM RELIEF VALVE.

The ideal site for a farm is on ground that is comparatively level and where the foundation can be either "all in fill" or "all in excavation." The reason is obvious: a tank built on ground partly filled and partly excavated is liable to be disrupted, where the foundation changes from cut to fill, owing to unequal settling of the ground, but in any case the preparation of a truly level surface is imperative. It is not necessary to point out the requisite measures to secure consistency of foundation, and the method of setting out grade stakes to ensure level is indicated in Fig. 2. As the bottom of the tank is composed of relatively thin plates ($\frac{5}{16}$ in.), care must be exercised to prevent deterioration from the corrosive action of alkaline salts contained in the soil on which the plates rest, and precautions must be taken to prevent water leaking through an imperfect seam and collecting beneath the tank bottom. Where oil sand is plentiful it is usual to place several inches on top of the foundation (Fig. 3), or the same effect can be produced by oiling the surface and working the oil in three or four inches by means of rakes. Some asphaltic or rust-resisting paint would naturally

* "Oil Storage Tanks and Reservoirs, with a brief discussion of losses of oil in storage and methods of prevention." By C. P. Bowie. Washington: Government Printing Office. [Price 25 cents.]

be applied to the lower surfaces of the bottom plates before being put in position.

The shell of the tank is built up of rings formed of plates, generally 5 ft. wide and 15 ft. long, 24 sheets thus completing the ring of the largest size tank practical for fabrication and construction in the field. The thickest plates, those at the bottom, weigh about 23 lbs. to the square foot. Six rings are required to give the necessary height, and the thickness of plates in each ring diminishes, till those at the top, weigh about 10 lbs. to the square foot. A tendency is noticeable to introduce larger and heavier plates so that only four rings, each of 7 ft. 6 in. shall be necessary to give the required height, at the same time increasing the length to 18 ft., reducing the number to 20 in the completed circle. By using such larger sheets, eliminating two horizontal and four vertical seams, the length of the riveted and calked joints is reduced by more than 15 per cent. This apparent advantage is offset in a great measure by the increased weight of metal, which it is necessary to put in the four-ringed tank, because of the greater thickness of material required to satisfy proper engineering design and the impracticability of rolling a taper sheet. Moreover the evil that the larger sheets is supposed to remove, or diminish, should not exist. The laps of sheets can be so effectively riveted and calked, that in the modern gas-tight tank there is no leak, but if from wear or unseen causes leaks do occur, they can be easily repaired because of their accessibility.

The construction of the roof presents some interesting points and no uniform practice is established. The material may be either of metal, or of wood covered with paper or with sheet iron, but considering the fire hazard an entirely metal roof seems preferable. It may be possible to extinguish burning oil in a tank by steam or a blanket of foam, but if the fire is on the roof, smouldering embers will drop back into the tank, reigniting the whole mass, though the blaze along the surface of the oil may be quenched. But if steel be the selected material the mode of construction may vary considerably. The steel may not be of sufficient thickness to admit of calking and red lead or some such material is placed between the laps of the sheets before riveting. The objection to this plan is that the light hydro-carbon gases rising from the oil may eat the saturating material and destroy the tightness of the joints. On the other hand, if such a thick steel is used that calking is possible, it is urged that the roof is continuously subject to expansion and contraction stresses, as well as to atmospheric pressures, which cause it to "breathe." Thus the seams are subjected to distortion, and it is questionable whether a calked joint can be kept tight. It must be admitted that the roof of the tank is the part that deteriorates most rapidly owing to the action of gases and the possible presence of sulphur, so that under any circumstances the life of the roof is liable to be shorter than that of other portions.

Wooden roofs are generally used as covers to heavy oils and consist of sheathing boards covered with roofing paper, rendered watertight by being immersed in a hot solution of asphaltic material and rolled under heat and pressure. Roof coverings are also built up with layers of building paper or burlap, coated and stuck together with asphaltum and having a pebble finish on top. An objection to such roofs is that if the wooden supports are not well seasoned, the cover will be torn apart in some places and puckered in others. Sheet-iron forms an admirable covering for wooden roofs, and Mr. Bowie admits that some he examined were quite reliable and resisted the passage of gases, but the construction has the disadvantage that the nails used for fastening the iron will soon become loose in the sheathing, on account of the wood having shrunk. There is the further danger that during a storm the wind may get under a sheet so loosened and tear the iron from the sheathing. Of course the same objection holds with the paper covered roof, and once the covering is gone, the wind will often wreck the sheathing and rafters as well.

Wind is a more formidable foe in the States than in this country and precautions have to be adopted against the dreaded tornado that we might neglect with safety. Such a tank as we are dealing with may be admirably designed to resist the pressure from within but is poorly equipped against wind stresses from without. A system of steel ties across the interior is recommended as a form of "wind bracing." These ties consist of flexible steel cables, ¾ in. diameter, across four diameters at right angles dividing the tank area into 45 deg. segments, and repeating this cross network at different levels about 10 ft. apart. At the centre of the tank the ties are attached to a heavy steel ring surrounding the centre post, and each radiating wire is provided with a turnbuckle, so that a practically uniform tension can be ensured, and maintained by adjustment from time to time. In districts visited by violent electrical storms it is further desirable to provide "explosion" doors to all storage tanks, whether intended for crude oil or light refined products. The provision of a reasonable number of vents will relieve the pressure caused by sudden expansion of gas and in case of ignition will generally save the shell, and often the roof. Eight explosion doors having each an area of 9 sq. ft. uniformly distributed, are recommended as suitable for large size tanks (Fig. 4, page 303).

The concrete-lined reservoir has proved a satisfactory container for fuel oils varying in gravity from 14 deg. to 18 deg. B, and the cost of erection reckoned on barrel capacity would probably be about one-third that of a steel tank. The war has made all estimates unreliable, but on pre-war prices such a tank as described here could have been built at a cost of 30 to 32 cents. per barrel: the concrete reservoir price would be about 11 cents., of which the earthwork would absorb 3.5, the roof 3.0, and the concrete lining 4.5 cents. Economy favours the reservoir, and this result is due in a great measure to the increased storage accommodation, reaching frequently a million barrels. The usual form is circular and the dimensions approximate to 500 ft. in diameter, 25 ft. deep, with a slope on the sides of 1 to 1. Successful construction depends on the preparation, mixing and tamping of the concrete, the object being to ensure a dense close-grained surface. There is no need to labour these points, they are sufficiently recognised in many works of construction. It is, however, satisfying to know that with proper precautions, an oil-tight structure can be made. Samples of concrete taken from the bottoms of reservoirs, which have been in use several years have shown no signs of penetration. This is the verdict not only of engineers who have applied mechanical tests, but a study of the chemical action of oil on concrete aggregates shows that dense concrete is impervious to oils of 13 deg. to 18 deg B, even when the oil is heated to a temperature of 120 deg. F.

The selection of site, the arrangement of effective drainage to prevent the collection of water behind the concrete lining that might exert a hydrostatic pressure on the sides or bottom, and the construction of the embankment all need the exercise of care, but call for no special remark. It is usual to

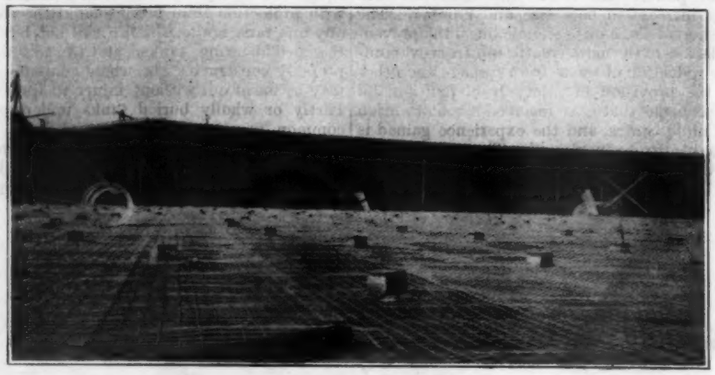

FIG. 5. ROOF OF LARGE RESERVOIR IN COURSE OF CONSTRUCTION.

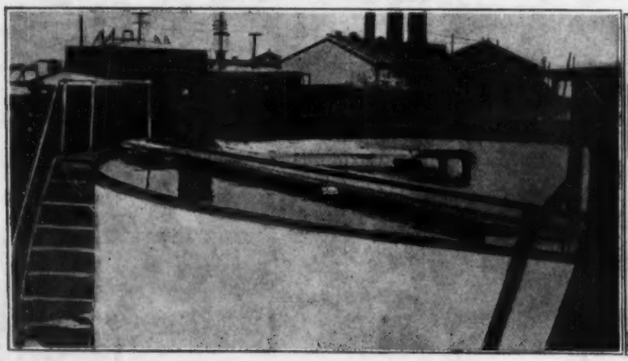

FIG. 6. STORAGE TANK WITH WATER SEALED TOP.

FIG. 7. SPRINKLER FOR COOLING TANK ROOF.

keep the outside slope of the embankment sprinkled with oil, a precaution that not only tends to consolidate the earth, but prevents the spread of vegetation, removing a possible chance of fire.

Roof construction demands more consideration. The materials used have been invariably wood covered with roofing paper. The general form is indicated in Fig. 5. This type of construction is considered uneconomical and capable of improvement. Wood and paper covering not only permits the sun's rays to penetrate and heat the upper surface of the oil but it offers no satisfactory resistance to the passage of the light hydrocarbon compounds that rise from the body of the oil by reason of such heating. The construction of a roof, some 180,000 sq. ft. in extent cannot be lightly undertaken, and Mr. Bowie's suggestion of a reinforced concrete roof made sufficiently strong to uphold a foot or more of earth, and tight enough to shed seepage water, may be a counsel of perfection, but unattainable in practice. It is eminently desirable to maintain a low and constant temperature within the reservoir, and such a non-conducting roofing would ensure this end, while probably the earth covering would prevent injuries to the concrete lining through expansion and contraction.

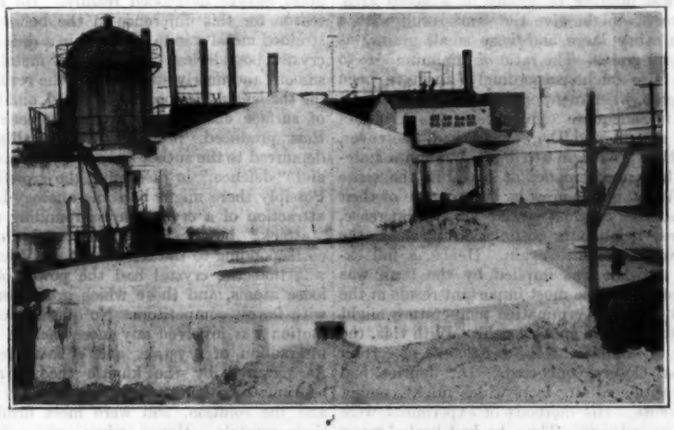

FIG. 8. REINFORCED CONCRETE TANK PARTIALLY UNDERGROUND.

Without close contact with operations in the field it is difficult to appreciate the amount of loss that accompanies storage in bulk, even under good conditions, or the importance of attention to the details mentioned. The loss here considered is altogether apart from the inevitable waste of hydrocarbon products that are constantly escaping from the wells, from the flow tanks in which the oil is collected, from the sump into which it has overflowed, and indeed from every surface freely exposed to the atmosphere. Transportation losses are necessarily large, the receiving tanks at the refineries are responsible for much waste, and if the total amount that disappears annually could be expressed in barrels, "we might well be staggered by the size of the figures." This is Mr. Bowie's deliberate conviction, and in these days when waste in any direction calls for severe censure, we would respectfully endorse his plea "for more definite and systematic efforts toward overcoming these losses than are at present exercised."

We are only concerned with those losses which occur after ingenuity and enlightened management have done what is possible to reduce the amount. As an instance of what may be effected by the judicious arrangement and handling of large storage, we may quote the example of a company, who used for some time reservoirs lined with clay or some close-grained impervious earth. The capacity of the reservoir was one million barrels, and from this one container alone, some 70,000 barrels vanished every year; either from evaporation or from seepage. By substituting a concrete lining the loss was reduced to less than one-third the amount, but even such loss is regrettable. It may be added that the saving in oil would cover the cost of the lining (practically £10,000) in little more than a year. In the case of a steel tank, where it may be assumed that there is no seepage and that the only loss is due to evaporation, the amount will depend mainly on the form of roof adopted. In the following table the loss experienced in a wooden roofed tank is contrasted with the loss from one supplied with a steel roof, at a farm at Port Arthur (Texas) where the temperature may occasionally reach 100 deg. F.

Character of Roof.	Gravity of Oil in Tank.	Depth of Oil in Tank.	Time of Storage.	Loss in Depth.	Loss in Barrels.	Percentage of Loss in Time.	Percentage of Loss in a Year.
	deg. B	ft. in.	days	in.			
Wooden ..	55.9	28 11	41	11¼	1.759	3.39	30.5
Steel roof ..	54.7	29 3¼	48	2¾	383	0.687	5.32

Other data point to very similar results, and on the average, the difference in favour of an all-steel construction amounts to about 22 per cent. With gasoline at say 15 cents a gallon at the refinery, this loss would amount to 75,500 dols. a year in a 55,000-barrel tank, "indicating that it is the height of folly to store gasoline even temporarily in a wooden-roof tank."

These figures might be extended to embrace various types of container and different grades of oil, but though the grievous character of the loss would be confirmed, the gain in statistical accuracy would be slight, for reliability does not increase with the number of instances cited. Petroleum is an extremely complex mixture of hydrocarbon combinations, having various gravities and boiling points. A crude oil with a gravity of 40 deg. B may be a compound of some heavy and some very light hydrocarbons, whereas another oil of the same gravity may be of a more homogeneous character. The first oil, parting readily with its lighter compounds, would evaporate much more readily in storage than the latter. And again oils of similar physical characteristics do not have the same coefficient of expansion. It is usual for commercial purposes to assume a general coefficient of expansion of 0.0005; but if this estimate were in error by the fifth part—a quite possible amount—it is easy to see that in a reservoir of one million barrel capacity, the contents would be erroneously calculated by 1,000 barrels for a 10 deg. F variation in temperature. Such a change might be effected by the mere colour of the paint applied to the outside of the tank. Some experiments on small tanks painted in various colours and submitted to the action of a powerful arc light for 15 minutes show that the rise in temperature of the contained benzine in a tank painted black is 31.5 deg. F. higher than in one painted white.

We cannot imagine that the contents of a concrete reservoir, however, would be noticeably effected by such a superficial gloss. The devices in use, for reducing evaporation aim at keeping the temperature low by more serious means, and are also directed to preventing leakage from the container. Unfortunately the arrangements in general use are only applicable to small tanks. A common form is the water-seal top (Fig. 6) suitable to tanks of about 5,000 barrel capacity in which naphthas and light refined products are received from the tail houses. Where the device is adopted the roof really takes the form of a shallow watertight tank, made of riveted plate and placed about 6 in. below the upper edge of the shell. This space is filled with water and kept cool by constant circulation. A relief vent may be fitted which permits the escape of gas through a water-seal and allows air to be taken in through a swing check valve open to a pressure from without, but closed to pressure from within the tank. It is claimed that the losses due to evaporation can be reduced 14 per cent. by this means. Sprinkling the roof by a spraying device readily suggests itself (Fig. 7) and is rendered more effective if the water on leaving the roof is deflected against the sides of the tank by a baffle plate, causing the water to pass in a film over the whole outside surface. The rapid evaporation from the thin sheet of water should prove very successful in reducing the temperature of the tank contents.

Small reinforced concrete tanks, having a capacity of about 1,500 barrels, partly buried underground, appear to be coming into vogue, and it is a form which would seem to be very suitable in this country where the demand for storage is limited by the amount of petroleum imported. These tanks are generally about 34 ft. in diameter and 10 ft. high, and are buried underground to within 3 or 4 ft. of the top (Fig. 8). There is no apparent reason for adhering to this size, and larger are in course of construction, the concrete walls being made proportionately more massive. In Texas, such tanks with a capacity of 400,000 gallons have been used successfully for storing oils ranging in gravity from 15 deg. to 30 deg. B. A similar tank after some years use was examined and showed no signs of leakage. In this particular tank, the concrete bottom was 17 in. thick, and the sides tapering towards the top to one foot, the height being 18 ft. The cost of erection of a tank of 15,000 barrels capacity is about 10,000 dols., but the cost per barrel diminishes with the size of the tank. A great future seems to lie before this form of storage for it is being adopted by many railways, light and power companies, and others who are large users of petroleum.

THE INSTITUTE OF METALS.

(*Concluded from page* 294.)

IN opening the proceedings, on Wednesday, the 11th inst., at the meeting of the Institute of Metals, in the rooms of the Chemical Society, the president Professor H. C. H. Carpenter, F.R.S., announced that the membership now exceeded 1,000, being constituted by four honorary members, 1,006 ordinary members, and 31 student members. During the past two years the membership had, he said, increased by nearly 400, and he thought that the estimate of an ultimate membership of 1,500, which he made some time since, would be attained much sooner than he had anticipated, even so recently as six months ago.

THE ESTIMATION OF PHOSPHORUS IN BRONZES.

The first paper taken was a note by Mr. T. E. Rooney, A.M.S.T., of the National Physical Laboratory, "On a Rapid Method of Estimating Phosphorus in Bronzes." The method described is based upon the well-known volumetric method of estimating phosphorous in steel. By comparative analyses made by the new method, and by the laborious Gravimetric method, the author proved the reliability of the procedure described in his note. We print this paper on page 332 of the present issue.

The discussion was opened by Dr. O. T. Hudson, who said that he was glad to note that the author had found that the method which was so successfully used in determining the phosphorous in steel, was equally good for bronze. The procedure was very clearly described, and the only possible difficulty the speaker could think of, was that a certain

amount of experience might, perhaps, be necessary to fix the time of digestion with the acid.

Professor T. Turner said that he presumed that when the ammonia was added to the solution, the amount was insufficient to neutralise the acidity.

Mr. E. L. Rhead stated that he had himself used a method of estimating phosphorus equivalent to that described by the author, and found it very accurate.

Mr. H. S. Primrose asked the author whether the coefficient in the formula used for reducing the observations was a theoretical one calculated from the chemical equation for the reaction, or whether the value of the constant was determined empirically, by comparing the results, obtained with the volumetric system of analysis, with absolute determinations by the gravimetric method. In the case of steel analysis, he stated that it was found necessary to use an empirical constant obtained by comparing the results obtained by the two methods.

Mr. Pile asked how long a time was necessary for the volumetric analysis, and whether it was essential to complete the analysis in one day, or whether it was possible at some stage to let matters stand over night.

In reply, Mr. Rooney said that the factor used in the formula adopted in reducing the observations was the same as employed for steel, which was, he thought, obtained by calculation and not empirically. In answer to the last speaker, he said that the analysis was best carried through on the one day. It was not safe to leave it over night, as the tin might come down. The time required was two to two and a half hours; one hour at least being necessary for the precipitate to settle out.

Grain Growth in Metals.

A paper by Mr. Zay-Jeffries, D.Sc., on "Grain Growth in Metals," was in the author's absence, read in abstract by Dr. G. H. Gulliver, and this was followed by a note on "Rapid Re-crystallisation in Deformed Non-Ferrous Metals," by Mr. D. Hanson, of the National Physical Laboratory. We commence the publication of Dr. Jeffries' paper on page 328, and we shall print Mr. Hanson's note in an early issue. The two papers were discussed, together.

Speaking on Dr. Jeffries' paper, Mr. Hanson said that this constituted a most notable contribution to our knowledge of grain growth in metals. The speaker's own results dealt with a special case of grain growth, and they were in good agreement with those of Dr. Jeffries. The latter had obtained his results by adjusting the experimental conditions so as to favour the development of certain grains, whilst restraining that of their neighbours. He agreed with many of Dr. Jeffries' conclusions, though he thought that others required further elucidation. Thus, "Germinative Temperature" was in one place defined as the temperature at which exaggerated growth occurred, but a comparison of two of the author's figures showed that this was incomplete, and that the definition should also comprise some reference to the degree of deformation to which the metal had been subjected, otherwise it would not be definite. Dr. Jeffries had claimed that the grains grew by migration of the boundaries of the grain, and not by the coalescence of neighbouring grains, and there was a good deal of evidence to support this view. In fact, grain growth often commenced at the junction of three crystal boundaries. As the constituents of the three adjoining crystals were differently oriented; if growth took place by coalescence, it might be expected that the orientation of one of the crystals would be more favourable to this than that of the other two, but as a matter of fact, no such selective growth was observed, the grain growing uniformly at the expense of all three. He did not understand the author's observations on the effect of the size of the grain fragments. It seemed to the speaker that it was not absolute size that was important, but the relative size. When a metal was deformed, an amorphous phase was produced which disappeared when the metal re-crystallised. In annealing such a deformed metal, the first effect of the treatment was to slightly increase the hardness, owing to the relief of the internal stresses, and the consequent slight increase in the amount of the amorphous phase. The next effect as the temperature rose was a softening of the material, which at times took place without, so far as could be seen, any accompanying structural change, and still higher temperatures were required for the production of visible grains. The speaker would suggest that the softening was due to the re-crystallisation of some of the amorphous phase, which might take place in different ways. In the case of hardened steel, the transformation suppressed by the hardening was, on re-heating the steel, effected at a lower temperature than that corresponding to the normal transition point. Similarly, he thought, that an undercooled liquid, such as the amorphous phase, might well re-crystallise at a temperature below the normal re-crystallisation temperature. The amorphous phase had much potential energy stored in it, in the shape of latent heat, and had a correspondingly high degree of instability, so that it was to be expected that it would re-crystallise easily.

Dr. G. H. Gulliver, who followed, said that in criticising the paper, he felt under a certain embarrassment, owing to a superabundance of material. The paper had its merits, but also its defects, the most serious of the latter being a lack of precision in the definitions given. This question of definition was, he said, all important in a paper of the kind under discussion. Thus, the author barely mentioned his method of determining grain size by counting the number of grains in a given area. Such a process might give the same result with a mixture of very large and very small grains, as with uniform grains. The ratio of minimum size to maximum size ought, accordingly, to have been stated. Again, when mention was made of grain-size contrast, no adequate explanation was given of what was meant, and Dr. Jeffries had, moreover, criticised the speaker, in attributing to him a statement he had never made, at least, in the sense implied. When grains grew at the expense of their neighbours, the contrast would at first increase, but if these neighbours entirely disappeared, the contrast would diminish again. Hence, a full explanation of what was implied by the term was highly necessary. The most important result in the paper was that the germinative temperature might be raised to the very melting point. With this, the possibility of diminishing the brittleness of certain alloys was closely connected. Dr. Jeffries had avoided mention of any facts which might conflict with his views. His methods of experiment were also open to criticism. Thus, he had heated wires by an electric current, and had assumed, without definite proof, that the sole effect of the current would be to heat the wire. The speaker thought, on the other hand, that the current might have a direct effect on grain growth. The view that grain growth took place by migration of the boundary was in accord with other experiments, and might well have been illustrated by diagrams. It was, in fact, quite possible to obtain on one and the same specimen consecutive sets of grain boundaries, viz., by first etching the specimen, then slightly reheating it, and again etching it. In this way superimposed on the structure before annealing would be found the boundaries of the grains as enlarged by the annealing. It was thus quite easy to see how one grain grew at the expense of others. In considering Dr. Jeffries' paper, it was important to remember that the observations were all surface observations, and the conditions in the mass might differ very materially from what would be inferred from these observations. He would also like to ask whether the author had really proved that one grain could exist inside a larger. The appearance might well be a mere intrusion of a neighbouring grain. Coming to Mr. Hanson's note, the speaker said that, dealing, as it did, with rolled metal, it was of great industrial interest. At the same time, it would be interesting to have similar experiments on unstrained metal. He wished that it had been possible to mark on the diagrams the limit of the permanent set. Distortion was often discontinuous in character. He suggested that, as in such experiments as Mr. Hanson's, the re-crystallisation took place very rapidly, it might be possible to measure the accompanying energy change, which was of the order of 10,000 to 15,000 ft.-lb. per lb. of metal involved, and half of this energy was liberated as heat.

Dr. W. Rosenhain said that he found himself largely in agreement with Dr. Jeffries' conclusions. It was quite true that the definitions given in the paper were not formal and precise, but he was not sure that this was a defect in this particular case. Qualitative characteristics were quite sufficient to lead to definite views as to grain size, and careful definitions were unnecessary here, however desirable they might be in other cases. It was no doubt quite true that large grains and small grains might exist side by side, but reference to the author's photographs showed there was no difficulty in classifying grain sizes. What mattered was the size of the largest, and it was quite easy to get a clear impression of what grain growth meant. The objection raised by Dr. Gulliver that the surface only of the metal was accessible was hardly valid, since in many cases the crystals went right through from one surface to the other. Some of Dr. Jeffries' conclusions, he might point out, had already been formulated by Professor Ewing and himself, in their paper of 1900, in which they discussed grain growth in lead. They then showed that no grain growth occurred in the cast metal. In fact, it was not possible to induce grain growth in a pure unstrained metal by simply annealing it. Even when lead was cast in a chill, there was no re-crystallisation on annealing it. If, however, it were previously strained, grain growth developed readily. He thought the reason for this difference in the behaviour of unstrained metal was to be found in a difference in the crystal boundaries. In the cast metal they were smooth and nearly straight. As the result of straining the boundaries became serrated, and the increase of surface energy due to the increase of surface thus produced, promoted re-crystallisation. He demurred to the author's use of the terms "attack" and "defence," in discussing the growth of grains. Possibly there might be some analogy between the attraction of a crystal on surrounding matter and "attack," but he could not conceive of anything corresponding to the term defence. What mattered was that the crystal had the power of absorbing loose atoms, and those which grow were the ones with fewest competitors. No question of perpetual motion was involved any more than in the mutual interaction of crystals, and a saturated solution. As pictured by the kinetic theory, atoms were continually passing to and fro between the crystal and the solution, and were most firmly held by large crystals. Hence, when only a few crystals were present, these would grow, but when fairly equal in size, there would not be growth. Thus, in casting an ingot in a chill, the temperature gradient near the surface was so steep that the crystals first formed had an advantage and became large accordingly. In the interior of the ingot the temperature gradient was weak, and the competition became more equal with the result that small equiaxed crystals were formed. So far back as 1900, the speaker had definitely proved that the grains grew by migration of their boundaries, by a series of experiments, in which freshly-crushed lead was etched, and subsequently annealed at 200 deg. C. Examinations made from time to time during the annealing showed the boundary migration very clearly.

Mr. Cosmo Johns said that, in his opinion, it would have been a waste of energy for Dr. Jeffries to have spent time in making precise grain measurements; there being no difficulty whatever in classifying the character of the grain in the photographs reproduced in the paper. One criticism might be made. There seemed to be some tendency in the paper to regard the existence of an amorphous phase between the crystal faces as a mere speculation, but following Poynting, Messrs. Johnson & Adams had shown that the existence of such a phase was a necessary consequence of accepted thermodynamic principles. They had proved, in short, that if a crystalline aggregate was subjected to shear, a liquid phase must be formed, which remained after the straining forces had ceased, as an undercooled liquid. On this head, a lot of evidence could be drawn from Dr. Jeffries' experiments with tungsten powder. The speaker took it that this powder was reduced *in situ*, and compressed into briquettes. The fact that it subsequently held together was proof that it had been strained and a liquid phase

produced accordingly, which, where it joined one fragment to another, served as a starting point for grain growth. This, however, might be interrupted by the presence of foreign particles. Dr. Jeffries had attempted to picture in detail the behaviour of the atoms at the crystalline boundaries. If his views were correct, they would go far to weaken our belief in the laws of thermodynamics. The speaker could not himself conceive of an atom giving up heat, and he thought that the author's representation of what occurred, went beyond the bounds of fair description.

Mr. Hanson, in reply, to the discussion on his paper, said that he had not attempted to determine the limit of permanent stretch on his specimens. It would be very difficult to do this, but he would make the attempt in any other work of similar kind, in which he might engage in the future.

The president, in bringing the discussion to a conclusion, observed that much recent work on grain growth had lately been done in America. Most of the results, unfortunately, had been published in a journal which had little circulation here. Mr. Hanson's paper was characterised by a certain precision. His illustrations really proved what they were said to do, which was not always the case with metallurgical papers, and further developments would be welcome.

Admiralty Bronze.

Mr. F. Johnson, M.Sc., then read a paper on "The Influence of Impurities on the Mechanical Properties of Admiralty Gun Metal." We reprint this paper on page 330.

The discussion was opened by Mr. Primrose, who said that the author had summarised in masterly fashion the work of other experimenters. He highly appreciated the reference to the work done by his brother and himself, which had made amply clear the enormous changes which could be effected by annealing gunmetal at appropriate temperatures, and had first put the matter on a practical basis. He was sorry that micrographs were not given in the paper, as this omission deprived the author of nearly half the available evidence.

Mr. M. T. Murray said that his experience with arsenic in gunmetal supported the conclusions reached by the author. His firm had found that the presence of small quantities, amounting to 0·3 per cent. to 0·4 per cent. in the copper used in making the bronze was distinctly beneficial, the improvement in the elongation being particularly marked. The elongation was, in a way, a criterion of soundness. This discovery of the good effect of arsenic was made by the unintentional and accidental use for bronze of an arsenical copper. He hoped the author would add to his paper some micrographs, showing the effect of arsenic on the structure of both the cast and the annealed gunmetal.

Mr. J. H. Gibson said that from the purely mechanical engineering point of view he was intensely interested in gunmetal, which was used for several distinct purposes. Thus, the Admiralty used it as a structural material for hulls, and the speaker was at times appalled at the consequent waste of good gunmetal thus used for purposes for which iron, cast-iron or commercial brass would do equally well. He had, for example, seen standards scrapped because the tensile strength was 13·8 instead of 14 tons per sq. in.

The rejected castings, in place of being heat treated, were sent to the foundry and scrapped. To facilitate the breaking up process, they were heated, the workmen judging of the temperature required by spitting on the metal. Gunmetal was also used for bearings, though it was not now usual to run iron or steel shafting on the gunmetal direct, but on white metal, the gunmetal serving merely as a cage. Here, again, the tensile strength of the metal was of little importance, provided it would stand up to its work. In fact, he had been making recently tests in which the "brass" was of cast-iron, and a load of no less than 4,200 lb. per sq. in. was successfully carried owing to the steps taken to ensure a continuous film of oil between journal and brass. Anything that could be done by heat treatment, or by addition of other material to save the present waste of gunmetal was of first importance.

Mr. L. Archbutt said that the paper gave a good deal of information of practical value. He could confirm the author's conclusions that a small quantity of arsenic had a beneficial effect.

In reply, Mr. F. Johnson said that lack of time was responsible for the omission of the micrographs, and this he would make good later on. As for arsenic, he had long felt that it was a friend to the copper metallurgist, but many engineers had regarded it as detrimental in copper alloys, and the evidence to the contrary would be highly appreciated by manufacturers. He agreed with Mr. Murray that a good elongation was evidence of a sound casting, but a certain reservation should be made, since it was quite possible to obtain sound castings showing a low elongation. He would suggest to Mr. Gibson that the material which he had referred to as being rejected for low-tensile strength, could easily be brought up to the standard by annealing.

Mr. Gibson explained that this was not permitted, the castings being rejected or accepted on the result of tests on specimen bars.

Disintegration of a Copper-Aluminium Alloy.

At the evening meeting on Wednesday, the 11th inst., Dr. R. Seligman read a note by himself and Mr. P. Williams on "A Peculiar Case of Disintegration of a Copper Aluminium Alloy."

The paper described a case in which certain aluminium wires, used to support slabs of gelatine, disintegrated, breaking up into loosely adhering grains, some of which were as much as 10 mm. long. Other aluminium wires used in the same way under identical conditions showed no deterioration. Analysis showed that the wires which failed contained about 2·65 per cent. of copper, whilst the sound wire was copper-free, and the break-up of the wire was attributed to its copper content. The authors suggested that a copper-aluminium eutectic was present which formed a sheath round grains of nearly pure aluminium, which were left free when the eutectic corroded away. We shall publish this paper in a future issue.

Mr. D. Hanson observed that some years since Carpenter had proved that copper was soluble on aluminium to the extent of 5 per cent., a solution of this richness could not, however, be obtained in a casting, but the latter might contain at least 2 per cent., and a further amount might be dissolved in drawing the metal into wire. He had therefore no doubt but that the 2·49 per cent. to 2·65 per cent. of copper found by the author in his aluminium was completely dissolved. He thought therefore that there would not be enough of the copper aluminium eutetic to form a sheath round the grains, as the authors had suggested.

Mr. E. L. Rhead said that the authors had stated that the wire was some years old, and he would ask if a definite date could be given. Some years ago he had had a somewhat similar experience with aluminium, but this was found to contain as impurities sodium, silicon and carbon. The product of the corrosion was a grey substance, and the defect was traced to the presence of the sodium. As now made aluminium was free from sodium.

Prof. H. C. H. Carpenter said that he agreed with Mr. Hanson that the explanation of the phenomenon suggested by the authors was probably incorrect He was glad to notice that Mr. Hanson confirmed the speaker's conclusion that aluminium could carry in solution 5 per cent. of copper. With 2¼ per cent. to 2⅝ per cent. of copper this copper was almost certainly wholly in solution. He feared the data were insufficient on which to found an alternative hypothesis to that of the authors, and this was very commonly the case when anomalies were met with in commercial metallurgy.

In reply, Dr. Seligman said that the theory criticised had not been put forward very definitely, but merely tentatively. In reply to Mr. Rhead, he would say that he could not fix the date of manufacture further than it was some five or six years back. The metal, however was of modern manufacture and contained no sodium. The other wire used contained no copper and did not corrode. No doubt the corrosion was, in some way, due to the copper and the physical conditions.

The Annealing of Aluminium Sheets.

Dr. Seligman next read in abstract a paper by Mr. R. J. Anderson on "Annealing Cold Rolled Aluminium Sheet by Abbreviated Exposures at various Temperatures."

In this paper the author explained that in American works practice it was usual to anneal aluminium for about 24 hours at 370 deg. C. His experiments showed, however, that very much shorter exposures gave better results. The effect of the annealing was tested by means of the Shore scleroscope and by the Erichsen tester. With the latter machine the sheet of aluminium is pressed into the form of a cup, and the figure of merit is represented by the depth of cup which can be formed before fracture occurs. The indications of this machine were found to form a better guide to the workability of the metal than the scleroscope. The scleroscope hardness number for the cold-rolled sheet was found to be 15, and the metal was considered to be "dead soft" when the hardness number was reduced to 4 or 5. The author found that this reduction in hardness could be effected in 10 minutes by using a sufficiently high temperature, and he stated that over-annealed metal proved unsatisfactory in drawing operations. In the course of his experiments the author observed that blistering was more common the thinner the plates. The blisters, it was stated, were always associated with dross. We shall print this paper in a future issue.

The discussion was opened by Captain L. Taverner, who asked what was meant by the author's statement that the metal was annealed for three minutes. Did it mean that the metal stayed in the furnace for three minutes, or that it was maintained at the temperature noted for a period of three minutes? He himself, using an electric furnace, had found that 10 minutes was necessary for the metal to acquire the furnace temperature. If an attempt were made to heat it more quickly there was great risk of going beyond the intended limit of temperature, particularly in the case of the bottom specimen. Further, with respect to the temperatures used for softening the metal, the speaker noted that it was only with 16-gauge metal that the highest temperature gave the highest Erichsen test. With the 24-gauge metal the lowest temperature gave the best test. He should also like to know why, in certain of the experiments, the metal was soaked for three hours at 475 deg. C., in view of the fact that the best Erichsen test was obtained with an annealing temperature of 400 deg. C. In some of the speaker's own experiments metal having a Shore hardness number of 15·0 gave, after exposure for one hour at 350 deg. C., a hardness number of 5 or 6. A similar exposure at 300 deg. C. yielded a Shore hardness number of 10 to 11, which, with six hours' exposure, fell to 5. To get an equal softening at 250 deg. C. required 200 hours. In the experiments made at 300 deg. C., the hardness number, after falling to 5, increased to 6, and then sank to 5 again, and finally to 2 or three, as the annealing was further prolonged.

Dr. A. G. C. Gwyer said that he noticed the author did not give particulars as to the mass of sheets annealed, which was a governing factor, and he would like to know whether American furnaces were larger than was customary here. In British practice the annealing was never prolonged over anything like the times mentioned in the author's paper as usual in American works. The abbreviated annealings advocated had been, in point of fact, the common practice in this country, and undoubtedly such an exposure as 24 hours at 370 deg. C. would yield a very inferior metal. The reference to the sluggishness with which aluminium annealed might convey the impression that a prolonged exposure was required to start recrystallisation. This was not the case, but the completion of the process did require time. With respect to the prolonged annealings stated as usual in the States, the speaker noticed that this description of American practice was confirmed by the Bureau of Standards, which in one of its publications gave 18 hours to 24 hours at 350 deg. C. as the normal time for annealing aluminium sheets. The author gave 15 as the scleroscope hardness number for cold rolled aluminium. In the speaker's own experience he had never found a lower number for the cold rolled metal than 18, and it was often 24 to 25. He had never, moreover, got a lower figure for the soft metal than 5, but had not tested greatly over-annealed sheets.

Moreover, the metal with which the speaker's experiments were made was much purer than that dealt with by the author, which contained ¼ per cent. of copper. The speaker would have accordingly expected higher hardness numbers from the less pure metal. Dr. Gwyer next exhibited a number of Erichsen test pieces. The specimens he exhibited were, Dr. Gwyer said, all cut from the same sheet but had undergone different heat treatments. With 20-gauge metal he had obtained with hard bright sheet a scleroscope hardness number of 19 and an Erichsen figure of 7·8. With metal of medium temper the corresponding numbers were 14·5 sclerescope and 8·05 Erichsen. With soft medium metal the figures were 12½ and 8·20, and with specially soft metal 11·25 and 4¾. In the Erichsen test the ordinary soft metal showed no sign of crumpling, whilst with the special soft this was marked. At first sight this might be attributed to excessive grain growth and consequent small crystalline strength. He had etched both specimens with hydrofluoric acid, which brought up nothing, but on taking micro sections enormous crystals were disclosed in the extra soft metal, and there was no doubt that the excessive growth had given rise to inter-crystalline weakness. This special soft material had not, he should say, been produced by ordinary annealing. The final thickness of the sheet was 0·036 in., but it had been annealed when the thickness was 0·040 in., and the subsequent work done on it was insufficient to restore the structure, and the Erichsen value was, in consequence, very poor. The other sheet which had a high Erichsen value had also a fine crystalline structure. These results had an important bearing on practice. Sheets were sometimes returned from manufacturers as poor, whereas what had happened was, that in drawing it or otherwise working it, the metal had been annealed at some stage and then insufficient work had been done on it, to restore its quality. The Erichsen machine was of great value for testing the suitability of the metal for drawing, the scleroscope being unsatisfactory for this purpose. There was too little distinction between the scleroscope numbers of a suitable and an unsuitable metal which might differ by less than ½, whilst the Erichsen figures would be as 9 to 11. Moreover, the Erichsen test was reliable whatever the gauge of the metal; whilst with thin sheets the indications of the scleroscope were affected by anvil action.

Dr. R. Seligman said that the last speaker had dealt with modern practice here, but in the past it was by no means unknown for rolling slabs to be left in the muffle over night, and it was well that the possibility of over-annealing should be made known. The author's results ought also to be brought before spinners and stampers. In the old days stampers often returned metal because it drew rough, and the makers did not then know the cause. He did not understand the frequent references to the extreme sluggishness with which aluminium was said to anneal. In the speaker's own experiments he had sometimes obtained complete relief of stress in a few seconds by simply dipping the specimen into the muffle and promptly removing it, the whole operation not lasting one minute. This could hardly be called sluggish annealing.

Interposing, Dr. Gwyer said that the special soft sheet to which he had referred and which had been annealed when ·040 in. thick and then rolled to ·036 in., would anneal extremely rapidly, but if it had been rolled to ·036 in. without the anneal when 040-in. thick it would anneal slowly. The growth after the start of re-crystallisation being very sluggish.

Continuing, Dr. Seligman criticised the author's method of experimenting, thick and thin places being annealed together. He asked if continuous annealing furnaces were in use, as he thought this type was hardly suitable, as it would be difficult to ensure that some of the metal did not reach a temperature outside of the somewhat narrow range to which this should be confined. He asked for further information as to the blisters referred to in the paper.

Dr. W. Rosenhain said that he could not for the present speak freely as to these blisters but might say that they were due to the essential qualities of the metal and not to the process of annealing. Like Dr. Gwyer he was surprised to learn that aluminium in works practice was ever annealed so long as twenty-four hours at 370 deg. As to the continuous furnace it was no doubt difficult to ensure that all the sheets reached the desired temperature, but he believed this could be overcome and the type of furnance could be successfully used should it prove worth while. He doubted, however, if this would be the case more particularly for large sheets as the space required would be enormous. As matters stood, large sheets were easily handled. If, however, the output of aluminium ever became comparable with that of steel the continuous furnace might prove of value, but this stage had not yet been reached. In laboratory work it was perfectly easy to keep the furnace at the desired temperature and leave the plate in till annealed. The time needed was, however, too long for the plan to be suitable in commercial work. There a hot furnace was used, and the time of exposure adjusted so as to let the plate just reach the desired temperature. A still better method was to let the plate heat up and the furnace cool down simultaneously, adjusting matters so that when both had reached the same temperature, this was the annealing temperature. In his opinion the scleroscope should never be used for testing sheet metal of any ordinary gauge—as the effect of the anvil vitiated the results observed. The Erichsen test on the other hand was quite satisfactory, and the plan of measuring the pressure required to punch a certain size of hole, was also a fair test of hardness.

Dr. Hatfield said he would like to confirm Dr. Rosenhain's remarks as to using the scleroscope for measuring the hardness of thin sheets. Of course if used under standard conditions, relatively correct results could be obtained, but he noted that Dr. Gwyer's figures for the scleroscope hardness of aluminium were not the same as those given by the author of the paper. As to blistering he had met with the same trouble with brass sheets and had not known how to overcome it. In the case of zinc it occurred even in the absence of dross.

A speaker whose name did not transpire said that blistering was caused by overheating the metal at some early stage of its history.

ALLOYS OF COPPER AND ZINC.

Mr. F. Johnson, B.Sc., next read a paper on "The Alloys of Copper and Zinc, an Investigation of some of their Mechanical Properties." This described an investigation carried out with the assistance of evening students at the Birmingham Technical School on the tensile strength and hardness of different alloys of copper and zinc. The observations made were not very numerous and the results were not in accord with the prior investigations of Turner and Murray or with the theory of Kurnakow and Zemczuzny. The experiments in short indicated a uniform hardness for all alloys containing from 95 per cent. to 70 per cent of copper. At the zinc end of the series no evidence was found of the sudden fall and subsequent sharp increase in hardness which had been reported by Turner and Murray. The wholly β solid solution (53 per cent. copper) was found to possess far better mechanical properties than had been attributed to it by previous workers.

The discussion was opened by Professor T. Turner who, whilst considering the research highly creditable to evening class students, objected that the conclusions reached were reported in such a fashion as to give the impression that the work done by Mr. Murray and himself had been invalidated. He noted that the tests recorded in the paper were made with chill cast and with annealed metal, whilst the speaker's own experiments had been conducted on cast metal. It was well-known that annealing tended to smooth out anomalies, and this might be to some extent responsible for the failure to detect the maximum at 80 per cent. copper found by Murray and himself. He agreed, however, that much more work yet remained to be done with these copper zinc alloys.

Mr. J. L. Haughton wished to associate himself with the view that much work yet remained to be done on the zinc copper alloys. He thought that the author's opinion (that a drastic annealing sufficient to eliminate the strains on the chilled castings was annealing enough) was incorrect. Admittedly the alloys were not in the equilibrium condition and hence it could hardly be expected that the results recorded would be in agreement with a theory which referred to alloys in full equilibrium. Some work on the tensile strength and hardness of copper alloys rich in zinc had been done at the National Physical Laboratory. The range covered was from pure zinc up to zinc with 10 per cent. of copper. The Brinell hardness results were in good agreement with Prof. Turner's, although Turner and Murray worked with sand-cast metal, whilst chilled castings were used at Teddington. These experiments thus supported Turner and Murray rather than the author. He would not claim that his specimens were in full equilibrium, but very great care had been taken in casting them, which was effected at a temperature of 20 deg. C., above the liquidus. The tensile tests were in fair agreement with those recorded by the author. As for the elongation, with pure zinc it was 33 per cent. and practically zero with 10 per cent. of copper.

Mr. O. W. Ellis said that he had made many observations on the Brinell hardness of alloys with from 50 per cent. to 100 per cent. of copper. For the range of from 70 per cent. to 100 per cent. of copper his own figures obtained with chill castings were in fair accord with the author's, but the tensile strength appeared to reach a maximum at about 80 per cent. of copper. His hardness tests with from 65 per cent. to 70 per cent. of copper gave most discordant results. As for the elongation, the speaker's experiments gave a figure of about 60 per cent. for the alloy containing 69 per cent. of copper, as against the 66 per cent. elongation recorded by the author.

Mr. M. T. Murray said he was glad to learn that the Teddington results confirmed those of Prof. Turner and the speaker. The hardness figures were really an addendum to their paper, as they had not set out to determine these. He noted that Mr. Ellis had found no trace of a maximum of hardness between 70 per cent. and 100 per cent. of copper, and this seemed curious. He thought a slight adjustment of the author's results might possibly be required, and might admit of a small maximum at about 80 per cent. of copper, but the effect would be less marked in an annealed than in a chill or sand casting. If the ingots were cast in an open top mould considerable differences would be found in specimens, cut from different regions.

In reply, Mr. F. Johnson said he had not meant in any way to imply that the results obtained by Prof. Turner and Mr. Murray were wrong. The paper had, however, been written in a great hurry, and was less carefully worded than would otherwise have been the case. He did not dispute that the observers in question obtained the results they stated with their castings, but had attempted to show that when, as in works practice, chilled castings were used, then the hardness did not vary in the same way. Mr. Haughton had drawn attention to the fact that the alloys experimented on by the author were not in equilibrium, but the idea of the tests was to find out what the properties of the metal were in works conditions. He might add that his casts were made in open moulds, but care was taken to select the specimens tested from the same part of the ingot in each case.

OIL FUEL FOR THE FOUNDRY.

A paper by Captain A. E. Plant, A.S.C., on the "Use of Oil Fuel in the Foundry in Urgent Exceptional Circumstances," was taken as read. We shall reprint it in a future issue. The meeting was then brought to a conclusion with a vote of thanks to the Chemical Society for the use of their rooms.

TEMPLETS, JIGS AND FIXTURES.
No. XII.

By JOSEPH HORNER.

IN most shops where massive work is handled numbers of fixtures are designed from time to time with the object of increasing and enlarging the utilities of the heavy machine tools. There is often no alternative between making these adjuncts and incurring the much greater expense of machines built specially for the purpose, the price of which

TEMPLETS, JIGS AND FIXTURES.

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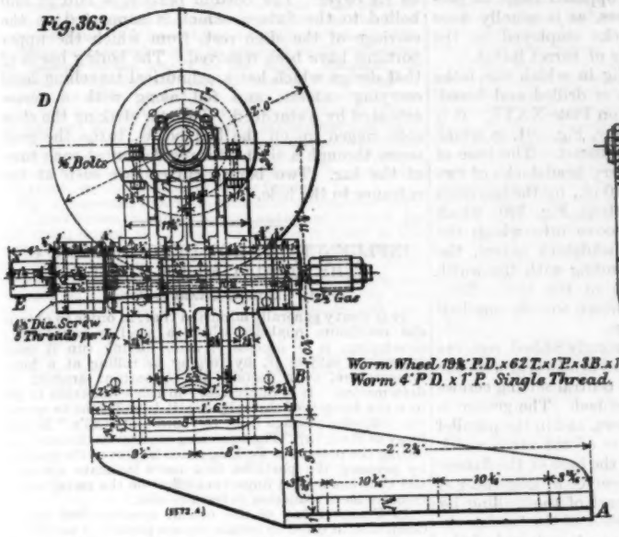
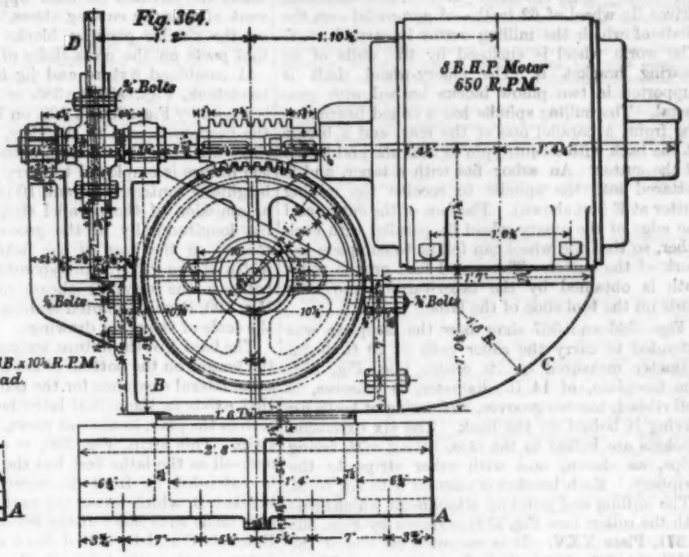
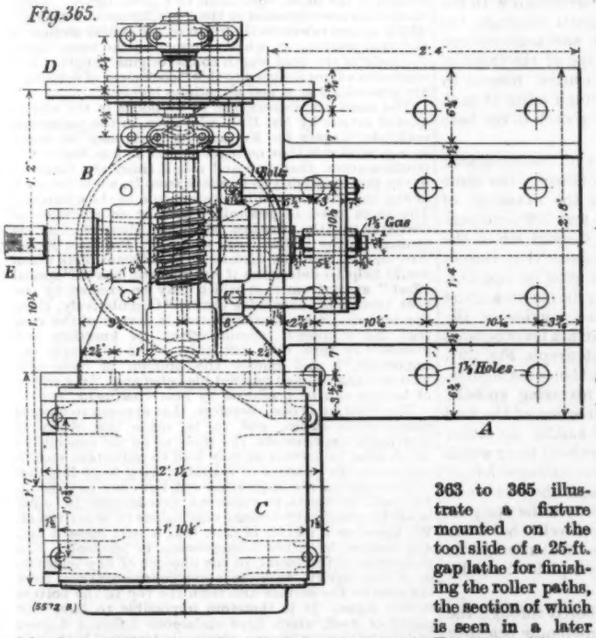
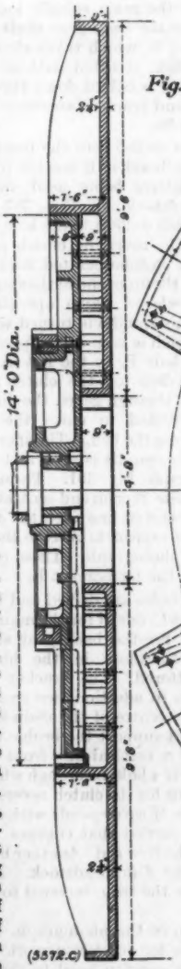
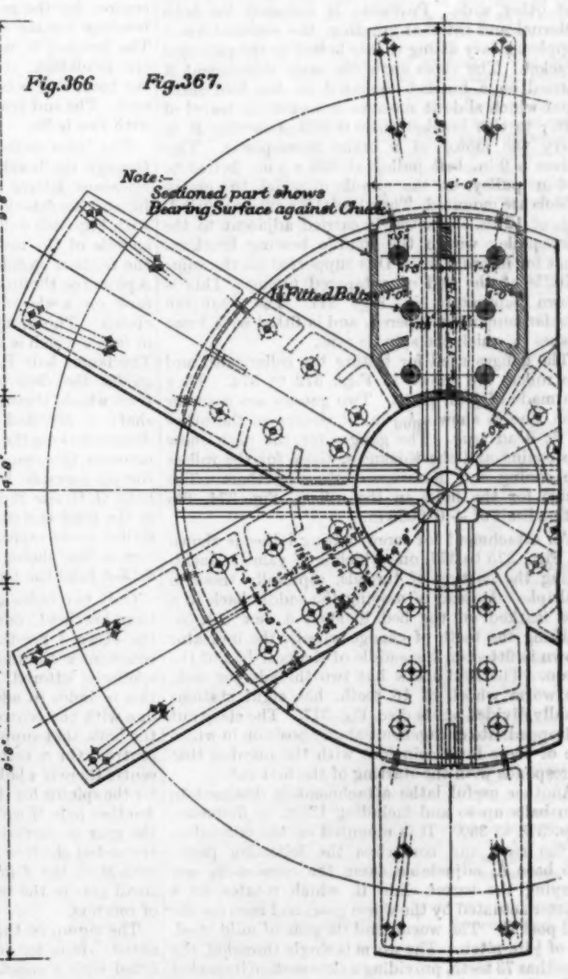










might be prohibitive, while the volume of work done would be insufficient to maintain them in regular occupation. The case is not comparable with that of small tools, the outlay for which is relatively moderate. Subsidiary fittings are often of a simple character, yet sometimes they are so elaborated that they become auxiliary machine tools, driven by their own independent motors. But when no alternative is possible, their expense must be incurred. In this article some examples of this kind are illustrated, supplied from the practice of Messrs. Glenfield and Kennedy, Limited, of Kilmarnock. The firm manufactures sluice valves and all classes of fittings for water and sewerage works, pumping and hydraulic machinery, nearly all this being of a heavy character.

Figs. 363 to 365 are to be taken in association with some succeeding illustrations which all relate to the tooling of roller paths and rollers made for swing bridges. These, it may be noted are similar to those used for heavy revolving cranes. Both paths and rollers are turned, milled, ground and gauged, ordinary machines being used for the work, supplemented with the attachments shown. Figs. 363 to 365 illustrate a fixture mounted on the tool slide of a 25-ft. gap lathe for finishing the roller paths, the section of which is seen in a later Fig., 372. The gap lathe has a 14-ft. faceplate, and as the roller path measures 10 ft. 4½ in. radius at its centre, extension brackets were fitted to it as shown in Figs. 366 and 367. Figs. 368 to 371, Plate XXV, illustrate an attachment made for grinding the rollers, which is mounted on one of the tool slides of the lathe, in which the rollers were turned. Since the lathe is provided with two tool slides, the turning and grinding were both done in one chucking.

The milling and grinding attachment for dealing with the roller paths is mounted on the tool slide of the 25-ft. gap lathe by means of the broad foot A, Figs. 363 to 365, which is secured with 12 bolts. A circular facing carries the main bracket B on which the mechanism is mounted. A bracket C, bolted to one side of this, receives an 8 brake horse-power motor, running at 650 r.p.m., so rendering

the fixture entirely self-contained. The motor shaft is coupled to a worm carried on the same shaft as the grinding wheel D, which is 2 ft. diameter. The worm—single-threaded—of steel, case-hardened, drives its wheel of 62 teeth—of gun-metal—on the shaft of which the milling cutter is carried at E. The worm wheel is enclosed by the walls of its bearing bracket B. The emery-wheel shaft is supported in two pillow blocks bushed with gun-metal. The milling spindle has a coned bearing at the front, a parallel one at the rear, and a bridge at the back with a centre pin to take the end thrust of the cutter. An arbor fits with a taper, and is cottared into the spindle to receive the milling cutter at E (not shown). The face of the cutter and the edge of the emery wheel lie parallel with each other, so that the wheel can follow to complete the work of the cutter. The coned face on the roller path is obtained by the taper-turning provision made on the tool slide of the lathe.

Figs. 366 and 367 show how the faceplate was extended to carry the roller path of 20 ft. 9 in. diameter measured on its centre line, Fig. 372. The faceplate, of 14 ft. diameter, is massive, is well ribbed, has tee grooves, and a ring of teeth for driving it bolted on the back. The six extension brackets are bolted to the face, fitting with facing strips, as shown, and with other strips to the periphery. Each bracket is secured with six bolts.

The milling and grinding attachment which deals with the rollers (see Fig. 373) is shown by Figs. 368 to 371, Plate XXV. It is mounted on one of the tool slides of the lathe, the rollers being turned from the other slide. Provision is included for both external and internal grinding, the second from a supplementary fitting that is bolted to the principal bracket. The views show the main attachment A carried on a bracket mounted on the tool slide, from which slide it receives a maximum travel of 2 ft.; to this bracket there is bolted another B, to carry the motor of 8 brake horse-power. This drives a 9-in. belt pulley at 650 r.p.m., belted to a 4-in. pulley, on the spindle of which the emery wheels are mounted. The wheel C for external grinding, of 12 in. diameter, is carried adjacent to the 4-in. pulley within the spindle bearing brackets. That for internal work D is supported on the same spindle at the end of a tapered fitting. This is shown separately in Fig. 371. The cast-iron tubular support is tapered, and is fitted with brass bushes in which the spindle runs.

The gauges used for testing the roller path and the rollers are shown in Figs. 372 to 374. They are made of ½-in. plate. Two gauges are used for each, one to show $\frac{1}{1000}$ in. of clearance, the other to fit dead true. The gauges for the path show the coning and the thickness, those for the rollers the coning and diameter—embracing them. The gauge for the holes in the rollers, Fig. 374, fits with a limit of + 0·0035 in.

An attachment for screw-cutting lathes is shown by Figs. 375 to 377, one which is of value in facilitating the cutting of threads, especially those in multiple. Instead of moving the saddle back to a line marked on the bed to start a new cut, or marking the teeth of change wheels, the indicator shown is fitted on the saddle of the gear-box of the apron. The lead screw has two threads per inch, the worm wheel, of 16 teeth, has eight stations equally divided on its disc, Fig. 377. The clasp nut is dropped into engagement at any position in which one of these lines coincides with the number that corresponds with the starting of the first cut.

Another useful lathe attachment is designed to turn balls up to and including 12 in. in diameter, Figs. 378 to 380. It is mounted on the cross-slide of the rest, and comprises the following parts. The base A, adjustable along the cross-slide, and carrying the turret slide B, which rotates on a register actuated by the worm gear, and receives the tool post C. The worm, and its gear of mild steel, are of ½ in. pitch. The worm is single threaded, the wheel has 73 teeth, providing a slow motion imparted by hand with a lever, or a hand wheel at the end of the worm spindle D, which is carried in a long bearing screwed to the base with four bolts. The wheel turns on a pivot in the base, seen in Fig. 379, being held down with two nuts. The tool slide is adjusted radially with a screw E working in a gun-metal nut in the bottom of the slide. The tool post is slotted to receive the turning tool, the height of which is adjusted with the wedge blocks, Fig. 381. These are serrated on their opposed faces to prevent slip under cutting stress, as is usually done on the similar packing blocks employed in the tool posts on the cross-slides of turret lathes.

A combined fixture and jig in which the lathe headstock, Figs. 382 to 385, is drilled and bored, is shown by Figs. 386 to 390, on Plate XXVI. It is the headstock seen in the view, Fig. 391, in which rings are being bored from a turret. The base of the fixture is employed to carry headstocks of two heights of centres, 8 in. and 10 in., by the insertion or omission of the parallel strip, Fig. 390, which fits longitudinally in the groove into which the tongue on the base of the headstock enters, the width of the groove corresponding with the width between the ways or shears of the bed. This, Fig. 390, it will be noted is drawn to only one-half the scale of the other drawings.

The base A of the fixture, strongly ribbed, receives the tongue on the bottom of the headstock, with the same lateral clearance for the central setting screws that exists in the actual lathe bed. The groove is seen in the plan, in the end views, and in the parallel strip. This strip, Fig. 390, is of the same width over-all as the lathe bed, but the base of the fixture is extended in front to receive a longitudinal bracket B, which forms the part of the drilling jig that deals with holes at the front of the headstock. Brackets C and D, bolted down at each end of the fixture, contain the holes which correspond with the centres for the main spindle journal bearings, the bearings for the back gear shaft, and some others. The bracket B, which takes charge of the front of the headstock, is fitted with a central tongue to the base, and is bolted down through a lug at each end. The end brackets are secured each to the base with two bolts.

The holes drilled into the front of the headstock through the bracket B are the following, the same reference letters being used on the drawings of jig and headstock: E, Figs. 387 and 389 (compare with Figs. 383 to 385), is the hole through which the spindle of the reversing clutch passes that throws the friction clutch-operated back gear in and out. A pinion on the inner end of the spindle moves a short rack on a sleeve which operates toggles in the clutch. This spindle is turned with a lever outside in front, which is seen in the photograph, Fig. 391. The larger hole F, to the left in the same figures, guides the drill for the clutch-reversing spindle, from which, through gears, the direction of the feed shaft is reversed to move the saddle in either direction along the bed. The short bent lever which actuates this spindle is seen at the extreme left of the photograph, Fig. 391. Through the two small holes G, G, one at each end central with the uprights of the head and in line with the oil wells, holes are drilled to be tapped to receive the bent lubricators seen in the photograph. These complete the holes drilled from the jig bracket B.

Only two holes are drilled and bored through the front bracket C, one H for the main-spindle bearings the other J for the back gear shaft, which holes coincide with those in the hinder bracket D, similarly lettered. The bracket D, which carries this includes in addition two small holes K, K, in line with the centre of the main spindle, to receive the bolts that support the bridge-piece for the back centre. On a vertical line from the main spindle centre there is a hole L through which boring is done for the spindle for the clutch-reverse for the feed rod. Another hole M corresponds with the stud on which the gear is carried that engages with the gear on the end of the feed rod. Another hole N corresponds with M in the 8-in. headstock. A hole O is for a small gear in the train inserted to give the change of rotation.

The rig-up in the photograph, Fig. 391, may be noted. It is for repetition work on a plain lathe fitted with a capstan head to the slide rest. The rings seen are gripped in an ordinary jaw chuck with false jaws, and are bored with three cutter heads, roughing and finishing, each head carrying two cutters. Each is guided, and the overhang steadied with a pilot entering the hole in the faceplate.

Fig. 392 shows an ordinary break lathe with a fixture rigged up to hold a steel clip for boring. The clip, in two parts, has a long lug or projection on its cover. The bottom portion is laid in and bolted to the fixture, which is supported on the carriage of the slide rest, from which the upper portions have been removed. The boring bar is of that design which has a cylindrical travelling head carrying cutters, and fed along with a screw actuated by a star-feed. The star striking the stop seen rigged up on the bed below, turns the feed screw through a sixth of a revolution at each turn of the bar. Two boring cutters are seen at the entrance to the hole.

INFLUENCE OF HOT-DEFORMATION ON THE QUALITIES OF STEEL.*

By GEORGES CHARPY, Paris.

It is pretty generally admitted that, in order to obtain the maximum qualities which a steel is capable of developing, it is necessary, after having run it into ingots, to subject it, by forging or rolling at a high temperature, to a certain and important amount of deformation. It is unnecessary in this connection to go into the history of the subject; it is sufficient to quote the following passage from Harbord and Hall's "Metallurgy of Steel":† "The squeezing exerted on the exterior during the process of working much improves the quality by pressing the particles into more intimate contact, and thus has a most important effect on the metal apart from its mere reduction in form or size."

In France many of the official specifications lay it down that in order to obtain certain parts it is necessary to effect, by means of forging, a reduction of the initial section of the ingot, equivalent to a given figure. These conditions are expressed as the "coefficient of working," which is equivalent to the ratio of the initial section to the final section, or, what amounts to the same thing, the ratio of the final length to the original length. The minimum values assigned to this "coefficient of working" are generally 3 or 4, and sometimes higher.

The same prepossession is to be noted in the above-quoted article by Mr. Hall, who says, in the paragraph entitled "Ingots for Forgings": "It may be taken as a general rule that no ingot should be less, under any circumstances, than one and a-half times the diameter of the shaft intended to be made from it, while for work of any importance two diameters should be the minimum. The ingot used is generally three or four times the diameter of the finished shaft."‡ However, in his treatise on the "Metallurgy of Steel," Professor Howe, after having carefully discussed the different facts which would help to determine if hot-working has a "special effect" apart from that which may be exerted by the heat treatment, concludes that: "Cumulatively, then, the evidence raises a presumption in favour of the view that the supposed 'special effect' of kneading and pressure as such does not exist or is relatively unimportant,"§ and quotes the opinion of Tchernoff, who said that he had verified his belief that "the effects of forging can be produced by heat treatment."‖

The question is one, therefore, that appears to deserve examination afresh, and to be made the object of systematic experiments, the more so as the conclusions which may be arrived at may lead to important modifications in the practice of manufacturing large forgings.

The experiments in question will, however, be difficult, and will necessitate numerous precautions in order to enable practically definite conclusions to be arrived at. We know, as a matter of fact, that a steel ingot is not, and cannot be either homogeneous or isotropic. The properties of the metal, in the absence of any inclusion or of any cavity, vary, in a continuous manner, from the axis to the surface and from the top to the bottom of the ingot. It is therefore impossible to have two pieces of steel, which have undergone different degrees of deformation by forging, rigorously identical both as to chemical composition and initial structure. It is possible, however, to get an approximate solution sufficient to form the basis of an opinion, on condition of taking certain precautions, on the nature of which it will be wise to lay some little emphasis.

I.

It should be noted at the outset that in order to study the influence of hot-working on the properties of steel, it is necessary to take into consideration the local deformation undergone at the very point from which the test-piece intended to represent the quality of the metal is to be taken. If the external form of the finished piece be the only guidance afforded in this direction, it should nevertheless be possible to assume that the deformation has been uniform, at least in certain well-determined localities. This simple remark is sufficient to exclude, from systematic experiments, the use of pieces obtained by forging under the hammer or the press, at any rate under ordinary conditions. The discontinuous action of such appliances will indeed necessarily produce extremely variable local deformations. The successive compressions which allow of there being effected, under the forge or the hammer, the shaping of a block of metal,

* Paper read before the Iron and Steel Institute, Thursday, September 12, 1918.
† London, 1907, page 284.
‡ *Ibid.*, page 458.
§ Page 249.

impart, to a given point in the ingot, a highly complicated path, in the course of which it alternately recedes and approaches the axis, the relative displacement of two neighbouring points being even much more irregular. It is only necessary to watch an ingot being forged under the hammer or the press, bearing in mind what has just been said, to realise the great importance of the local deformations; it is more difficult to follow them exactly. An approximate value may be assigned to the variations by making datum marks on the ingot. Amongst the numerous experiments carried out on this subject, which is a little beyond the scope of this paper, two only will be quoted; one, in which the datum points were traced on the exterior surface of the ingot and could be followed during the process of forging, and the other in which the datum points could be fixed in the actual interior of the ingot and could be discovered by sectioning the piece, on the conclusion of the forging.

Fig. 1, annexed, shows the successive dimensions given to a steel bloom, having a square section of 550 mm. by 550 mm., during the process of forging it down in the press to a section of 250 mm. by 250 mm. Equidistant datum points were marked on two of the faces. Their relative positions, after the different shaping passes, are marked on the corresponding figures. It is easily seen that they have diverged by variable amounts, and that the relative coefficients of working have varied during one forging and another.

After the first two forgings the average coefficient of working* is 1.5. The particular coefficients in regions indicated by datum points are as follows:—

$$\frac{A_1 B_1}{A B} = 1.38 \quad \frac{B_1 C_1}{B C} = 1.78 \quad \frac{C_1 D_1}{C D} = 1.32$$

$$\frac{D_1 E_1}{D E} = 1.50 \quad \frac{E_1 F_1}{E F} = 1.60$$

$$\frac{A'_1 B'_1}{A' B'} = 1.28 \quad \frac{B'_1 C'_1}{B' C'} = 2.15 \quad \frac{C'_1 D'_1}{C' D'} = 1.30$$

$$\frac{D'_1 E'_1}{D' E'} = 1.34 \quad \frac{E'_1 F'_1}{E' F'} = 1.50$$

After four forgings the total coefficient will be 3, and, in respect of the component coefficients:—

$$\frac{A_2 B_2}{A B} = 2.12 \quad \frac{B_2 C_2}{B C} = 5.4 \quad \frac{C_2 D_2}{C D} = 3.20$$

$$\frac{D_2 E_2}{D E} = 1.69 \quad \frac{E_2 F_2}{E F} = 2.80$$

$$\frac{A'_2 B'_2}{A' B'} = 2.65 \quad \frac{B'_2 C'_2}{B' C'} = 5.4 \quad \frac{C'_2 D'_2}{C' D'} = 1.80$$

$$\frac{D'_2 E'_2}{D' E'} = 1.80 \quad \frac{E'_2 F'_2}{E' F'} = 3.3$$

Finally, after six forgings, the total coefficient of working is 4.8, and the component coefficients are as follows:—

$$\frac{A_3 B_3}{AB} = 2{\cdot}78 \quad \frac{B_3 C_3}{BC} = 7{\cdot}30 \quad \frac{C_3 D_3}{CD} = 4{\cdot}10$$

$$\frac{D_3 E_3}{DE} = 2{\cdot}75 \quad \frac{E_3 F_3}{EF} = 3{\cdot}8$$

$$\frac{A'_3 B'_3}{A'B'} = 4{\cdot}38 \quad \frac{B'_3 C'_3}{B'C'} = 7{\cdot}30 \quad \frac{C'_3 D'_3}{C'D'} = 2{\cdot}37$$

$$\frac{D'_3 E'_3}{D'E'} = 5{\cdot}6 \quad \frac{E'_3 F'_3}{E'F'} = 4{\cdot}4$$

The component coefficients, the differences in which would be still more greatly accentuated if the datum points were closer together, already differ by considerable amounts from the average coefficient of working.

In another experiment an attempt was made to follow the deformations in the interior of the metal, a block of steel cylindrical in shape, with a diameter of 1.100 m., and a length of 1.450 m., being employed. Two holes were bored in this, 60 mm. in diameter, and 0.165 m. below the outer surface. These carefully-drilled holes were plugged by a series of small cylindrical rods 40 mm. in length, machined to exactly the same diameter, and forcibly driven home by means of screw plugs. These cylinders were prepared from two different steels, one having, as closely as possible, the same composition as the large block, and the other a composition which differed therefrom only in respect of having a somewhat higher percentage of manganese, the cylinders made from these two types of steel being alternated. This arrangement was selected in order to obtain a practically homogeneous block within which could be detected, after deformation, two lines originally rectilinear and graded in portions of equal length. The two steels employed for the little cylinders could, as a matter of fact, be regarded as having, at the temperature of forging, practically identical mechanical properties, while, on the other hand, it would be easy to detect them, after sectioning, by moistening the metal with tincture of iodine, which would strongly blacken the portions higher in manganese.

The block was forged under a 4,000-ton press and drawn down, in eight successive forgings, into a cylinder 525 mm. in diameter and 3.280 m. in length. The forging thus obtained was then sectionised, in the cold, along the diametrical plane cutting the two holes. The latter having undergone, during the forging, a slight torsional motion, it was found necessary to machine up the section and make it somewhat oblique in order to follow the axes of the holes. This operation was carried out easily enough by employing the iodine tincture to bring out the manganiferous cylinders which had become welded to the rest of the metal without any apparent break in their continuity, the mass represented in Fig. 2, page 312, being thus ultimately obtained. The positions of the cylinders could be detected very accurately, and have been plotted in Fig. 3. The surfaces of demarcation of the cylinders are perfectly distinct and allow of its being seen how, during the course of forging, the planes perpendicular to the axis have been deformed; there have been traced by dotted lines in Fig. 3 the approximate forms that can, in this way, be attributed, after forging, to sections originally plane. These tracings suffice to show, without its being necessary here to record the numerical measurements, the enormous differences in the local deformations which have been realised in regions corresponding with different parts of the surface. Apart from local inequalities due to the discontinuous mechanism of forging, which have caused the axes of the cylinders to approach and to recede from the surface instead of remaining parallel with the generating axes, it is highly interesting to note what has taken place at the extremities, where, as is natural, the phenomena is particularly disturbed. The free end is formed, as might be foreseen, by the folding back of the base of the original cylinder, which thus forms an important part

Fig. 1.

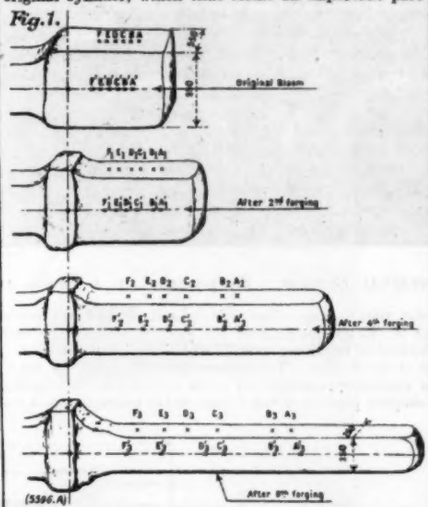


FIG. 1.—In the above it is possible to follow, during the course of forging, the displacements undergone by two series of six punch marks A B C D E F and A' B' C' D' E' F' struck at equal distances apart and in the centres of the two adjacent faces of a bloom 550 mm. by 550 mm., parallel with the edges of the bloom. If the deformations due to forging occurred uniformly over the whole length of the piece the punch marks would remain equidistant throughout the operations.

It is easily seen that this is not so. From the second forging the partial coefficients vary from 1·38 to 1·78 in the upper surface and from 1·28 to 2·15 in the lateral surface; after the sixth pass the partial coefficients vary from 2·75 to 7·3 in the upper surface and from 2·37 to 7·3 in the lateral surface for a total coefficient of working of 4·8.

The drawing out is therefore not a definite or uniform characteristic of a forging.

of the cylindrical surface. From the casting end and in the immediate vicinity of the undrawn-down portion of the ingot, a change has taken place in the direction of the curve of the deformed transverse sections, which produces a profound modification in the elongations realised at varying distances from the axis. This phenomenon occurs markedly in pieces which are drawn down from both ends in succession, as is very generally done, and in the median regions of such pieces which there is very seldom any occasion to examine.

If, instead of taking the very simple instance of a cylinder, transformed into another cylinder, more complicated forgings be taken into consideration, such as are involved in many ordinary pieces, it will be perfectly evident that the local deformations will be infinitely more diverse.

It may therefore be taken as an established fact that in a forging the deformation is very far from being uniform, and it is useless, therefore, to attempt to bring out clearly in evidence the effects of hot-working on the mechanical qualities of the steel by taking test pieces from forgings which have been subjected to more or less heavy drawing down. In rolling, the deformations are very much more regular than in forging, and they may be considered as practically uniform, at any rate in the direction of rolling. Lines originally parallel with the axis of rolling remain rectilinear and parallel during the course of deformation. It will suffice to quote one of the many experiments carried out to verify this conclusion. A cylindrical steel bar was bored along its axis, and the resulting hole very accurately filled by a round rod of steel of the same type but containing more manganese. The bar was cut into two portions, which were subsequently transformed into cylinders of half the diameter, either by rolling or by forging; the cylinders were sectionised along the plane of their diameters and the sections etched with iodine. Fig. 4, page 313, gives photographs of the sections thus obtained. In the forged bar we find the inequalities already described in analogous cases in the preceding paragraph, but in the rolled bar the cylinders have remained regular and concentric. The same result has been obtained by varying, in different ways, the conditions of the experiment.

It may thus be recognised that the rolling of an ingot into bars introduces no dissymmetry along its axis; test-pieces taken from the same bar at equal distances from the axis may be regarded as having undergone exactly the same deformation. It would, perhaps, be straining matters to extend this conclusion to test pieces taken at different points in the same traverse section, but there is, on the other hand, a dominant reason to forego comparison of such test-pieces owing to the variations in composition and in structure which are inevitable in the transverse sections of any ingot. This can be seen in comparing two bars of different sections by collating the results furnished by test-pieces taken from regions corresponding with the same fractions of the total radius, and therefore with the same region in the motor ingot.

II.

The author will now describe certain experiments carried out, and, bearing in mind what has already been said, will endeavour to determine the influence of hot-working on the properties of steel.

Experiment No. 1.—Three identical ingots, of square section with rounded corners (355 mm. by 355 mm. were cast simultaneously. The metal employed was a gun steel, made in an acid furnace from very pure materials—that is to say, of the quality which will best serve to obtain satisfactory results in tests from bars cut across (perpendicular to the direction of drawing down). These three ingots, regarded as identical, were rolled after having been heated under exactly the same conditions, and reduced to the dimensions of 225 mm. by 225 mm. for the first, 165 mm. by 165 mm. for the second, and 125 mm. by 125 mm. for the third. The coefficients of working were thus 1.7, 3.2 and 6.1. From each of the resulting blooms test-pieces were taken for tensile tests, for shock bend tests, and for notch tests, with both longitudinal and cross notches. These test bars were all cut from points taken from the same regions of the ingot both in the longitudinal and transverse directions, and were situated at one-third of the distance between the surface and the axis so as to avoid the influence of segregation and of axial porosities; their axes were thus identical from all points of view, except from that of the "coefficient of working." The bars themselves were slightly different inasmuch as, having the same ultimate dimensions, they comprised portions of the metal of the ingot spread, more or less widely, around the axis. Seeing, however, that this metal only occupied a small portion of the section, these differences can, in the author's opinion, be regarded as negligible.

The test bars were quenched and annealed under exactly similar conditions (quenched from 850 deg. and annealed at 600 deg. C.), and then subjected to tests. The following results were obtained:—

(*a*) *Tensile Tests.*—The tensile strength of each is practically the same; the elongations increase slightly, in the longitudinal samples, under hot working and decrease notably in the transverse test bars, and the same thing, only much more markedly, occurs in regard to the reductions in area. It is, however, the variation in reduction of area which alone influences the total elongation; the curves of tensile strength being practically identical and superimposable, up to the breaking-point.

Coefficient of Working.	Longitudinal Tests.			Transverse Tests.		
	Tensile Strength	Elongation.	Reduction in Area.	Tensile Strength	Elongation.	Reduction in Area.
1·7	91·2	20	111	90·9	18	76
3·2	91·6	20	140	90·5	16	57
6·1	90·5	22	170	90·6	12	31

The fractures vary naturally with the reductions in area; they are normal even in the transverse bars in the case of the bloom which has undergone little deformation, and take an oblique form in the transverse bars which have been strongly worked. Fig. 5, page 313, is a photograph of the bars tested.

(*b*) *Impact Bend Tests.*—The tests were made on two bars 24 mm. by 9 mm. by 75 mm., clamped at one end and subjected to the impact of a 10-kg. tup falling from a height of 1 m.

None of the longitudinal bars could be broken by impact. The transverse bars broke respectively after 29, 27 and 23 blows.

(*c*) *Impact Tests on Notched Bars.*—The bars, measuring 10 mm. by 10 mm. by 53.5 mm., were notched half-way through and tested under the drop test machine. Two bars were tested from each bloom, the notches being given the two rectangular positions possible in the circumstances. The figures given show the work absorbed by rupture, expressed in kilogrammetres and calculated per square centimetre of the section at rupture.

Coefficient of Working.	Longitudinal Tests.		Transverse Tests.	
	1.	2.	1.	2.
1·7	6·5	7·1	5·3	5·8
3·2	7·9	8·3	3·9	4·1
6·1	9·9	10·1	3·5	3·5

The variations are here much more marked and most sharply defined. Hot working increases the impact

*[The author uses, in this connection, the word *étirage*, which, when expressed as a ratio, has been translated into "coefficient of working." For the verb *étirer*, the phrase "drawn down" has been used as best expressing the author's meaning.—*Note by* TRANSLATOR.]

resistance longitudinally and diminishes it greatly in the transverse direction, the more so the greater the amount of deformation. Within the limits of the experiment the average differs but slightly.

Second Experiment.—Instead of taking several different ingots two fragments from the same ingot (the same metal as in the preceding experiment), subjected to different amounts of working, were compared. To begin with and in the first heat the section was reduced from qualitative nature obtained earlier.* If it be that no evidence to the contrary was observed, it may be regarded as an established fact that the hot-working of steel does not appreciably affect the tensile strength, or the corresponding elongation, either longitudinally or transversely. On the other hand, hot-working improves the reduction of area, the resistance to impact, and the impact resistance longitudinally, and considerably diminishes these values transversely.

The extent of the variations depends on the nature of the metals; it is much more marked in metals of mediocre purity, such as that employed in the third experiment (phosphorus 0.05 per cent. and sulphur 0.06 per cent.), than in very pure and dense metals, such as those employed in the first two experiments (phosphorus 0.02 per cent. and sulphur 0.015 per cent.). The difference will be still more marked in still more unsound and impure metals such as are often employed,

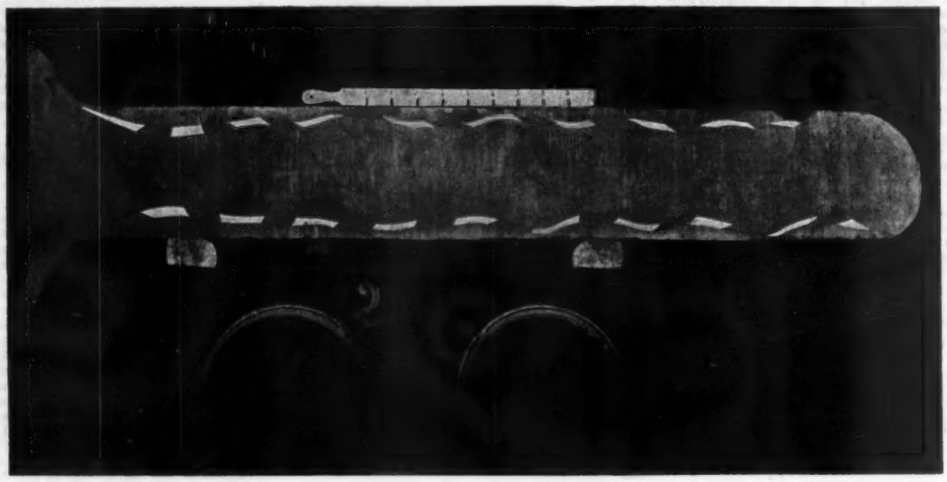


FIG. 2. LONGITUDINAL SECTION: PHOTOGRAPH OF A BLOCK AFTER FORGING.

This photograph shows what has become, after forging, of two series of rods plugged into two holes bored parallel with the axis of a cylindrical mass at a distance of 165 millimetres from the exterior. It will be seen that the axis of the series has assumed an undulating form instead of remaining parallel with its original direction. At the free extremities the rods outcrop on the exterior surface of the forging. Throughout the whole length of the forging the contact surfaces of any two successive rods, instead of remaining perpendicular to the axis, assume varying angles. In this case the mechanical operation was reduced to the simplest phase as it was limited to the production of a smaller shaft from a larger one.

355 mm. by 355 mm. to 225 mm. by 225 mm. (coefficient = 1.7), and, secondly, a piece of the bloom thus obtained was submitted to a second heat and the section reduced to 125 mm. by 125 mm. (total coefficient = 6.1). The piece from the first bloom, which had not been re-rolled, was replaced in the reheating furnace at the same time as the second piece, so that it should undergo the same heat treatment. The results agreed completely with those of the preceding experiment.

(*a*) *Tensile Tests.*

Coefficient of working.	Longitudinal Tests.			Transverse Tests.		
	Tensile Strength	Elongation.	Reduction in Area.	Tensile Strength	Elongation.	Reduction in Area.
1·7	91·6	18	110	92·2	18	87
6·1	91·3	22	165	92·5	14	54

(*b*) *Impact Bend Tests.*—The two longitudinal bars did not break; neither did the transverse test bar, which had been but little worked. The transverse test bar which had undergone most working broke at the forty-second blow from the tup.

(*c*) *Impact Tests on Notched Bars.*

Coefficient of Working.	Longitudinal Tests.		Transverse Tests.	
	1.	2.	1.	2.
1·7	7·5	7·5	5·3	6·0
6·1	9·3	9·5	3·5	3·2

Third Experiment.—The preceding experiments were carried out on metal chosen in such a manner as to eliminate, as far as possible, the differences between the test bars taken, both in regard to the amount of work they had undergone and in regard to its direction. It appeared necessary to try the second experiment over again on a metal of the same grade and of current quality (semi-hard basic steel, as used in the manufacture of shells).

An ingot, 355 mm. by 355 mm., was taken and treated exactly as described above, except that in the heat treatment of the bars annealing was carried out at a higher temperature (650 deg. C.) than in the preceding case, so as to diminish the increase in the tensile strength due to quenching and to get the metal into the condition of minimum brittleness. The results obtained are given in the paragraphs (*a*), (*b*) and (*c*) in the adjoining column.

The experiments which have just been described, carried out under conditions as clearly defined as possible, and with the object of ascertaining the influence of hot-working, confirm and emphasise a series of results of a

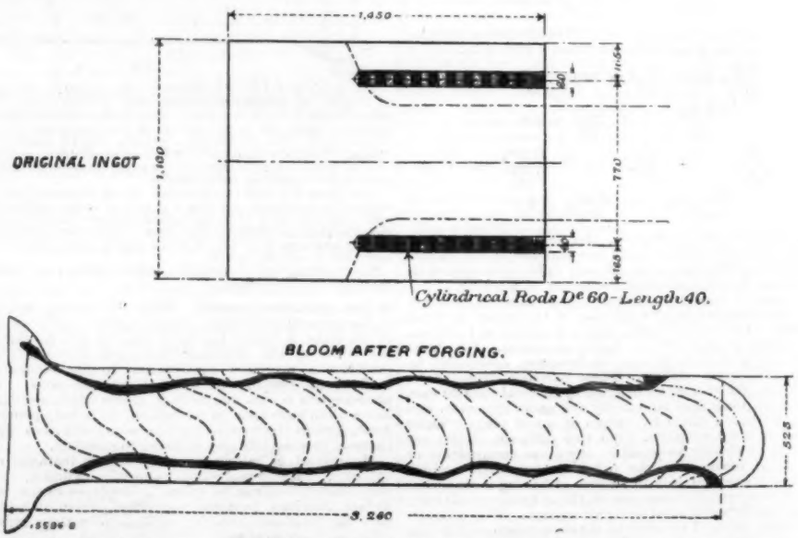


FIG. 3.—The upper drawing represents the section of the original ingot across the diametrical plane cutting the axes of the two bands of rolls; the dotted lines show the section after forging.
The lower drawing shows the section after forging. The dotted lines show how, judging from the angles assumed by the contact surfaces of any two adjacent rods, the planes, originally perpendicular with the axis, have become deformed during the course of forging.

(*a*) *Tensile Tests (Third Experiment).*

Coefficient of Working	Longitudinal Tests.			Transverse Tests.		
	Tensile Strength	Elongation.	Reduction in Area.	Tensile Strength	Elongation.	Reduction in Area.
1·7	70·1	18	33·0	70·7	11	27
6·1	72·7	23	60·5	68·4	4	8

(*b*) *Impact Bend Tests.*—The two longitudinal bars broke after 17 and 40 blows from the tup respectively. The two transverse bars broke after the eighth blow.

(*c*) *Notched Bar Tests (Third Experiment).*

Coefficient of Working.	Longitudinal Tests.	Transverse Tests.
1·7	3·50	2·00
6·1	9·10	1·50

and in which the elongations and the impact resistance transversely become practically nil once the drawing out reaches a given value.

The favourable influence attributed to hot-working rests therefore solely on the fact that in the bulk of the cases only the results of longitudinal tests have been taken into consideration, and that the conclusions arrived at have been unduly extended to certain products, such as gun steel, for which, nevertheless, transverse tests are required. This conclusion has been made the

* See, in particular, the bearing of the results obtained on pieces of the same shape obtained by starting with different ingots after drawing down from 1.27 to 11.88, and given in "Conditions et Essais de Réception des Métaux." Paris: Dunod and Pinat, 1917.

subject of different check experiments, amongst which it will be sufficient to quote the following :—

From the same cast of semi-hard open-hearth steel, obtained in an acid furnace by melting very pure materials, there were prepared, on the one hand, an ingot of 800 kg. and 8.6 sq. decimetres in average section, and, on the other hand, an ingot of 10,000 kg. and 61 sq. decimetres section. These ingots were used to prepare, by forging, the oval-shaped cylindrical pieces shown in Fig. 6, annexed, in which there has been superimposed in each case the outline of the ingot (in broken line) and the outline of the forging made therefrom (in unbroken line). The reduction in section was thus but slight in the case of the small ingot and exceedingly high in the large ingot. The resulting pieces were, after forging, subjected simultaneously, in the same furnace, to a heat treatment that comprised a quenching in water from 850 deg. C. and an annealing at about 600 deg. Test-pieces for tensile tests and impact bend tests were subsequently taken from both ends, and at right angles to the direction of forging. The tests yielded the results summarised in the table annexed.

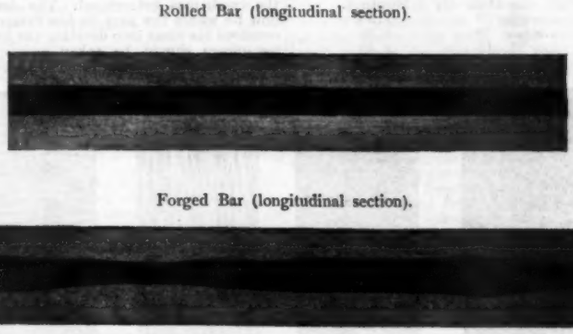


FIG. 4.—It is shown, from above, that rolling has the advantage, over forging, of not introducing any dissymmetry in relation with the axis of the resulting bar

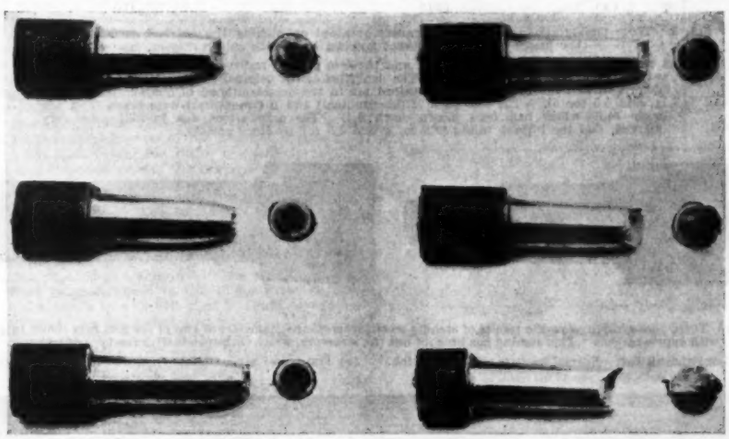


FIG. 5.—This photograph shows the fractures, in profile and plan, of six test bars. On the left the bars were taken parallel with the direction of rolling (longitudinally) ; on the right, at right angles to the direction of rolling (transversely). Each pair (horizontally) were taken from the same bloom.

The two upper test pieces correspond with a coefficient of working of 1·7. The fractures are practically alike.

The two lower test pieces correspond with a coefficient of 6·1 ; the elongations and contractions were 22 and 170 respectively for the longitudinal bar ; and 12 and 31 for the transverse bar. The fracture of the longitudinal bar (on the left) is a good fracture of the cup type, with considerable contraction ; that of the transverse bar (right side) is oblique and the contraction is practically nil. In the case of the centre test pieces the mechanical properties are intermediate.

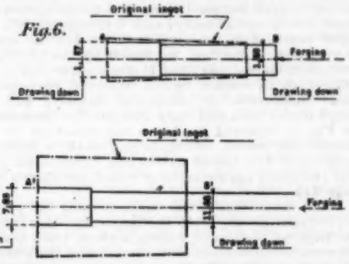
It will be seen that the results obtained with bars from the large ingot are distinctly inferior to those obtained with bars from the small ingot. It would therefore appear to be a certainly that, in regard to pieces tested transversely, a mistake is made every time an attempt is made to improve the quality by increasing the amount by which the metal is drawn down. In regard to all other metal parts it is necessary, in order to ascertain in what instances hot-working may be of use, to appreciate the relative amounts of deformation undergone longitudinally, transversely and at various obliquities. This constitutes a problem respecting the strength of metals which is completely beyond the scope of this paper, and to the importance of which reference can alone be made here. It is, however, probable that the instances in which hot-working is injurious are fairly numerous.

Point from which Test-pieces were taken.	Coefficient of Working.	Tensile Tests on Bars measuring 13 mm. by 8 mm. in Diameter taken Transversely.			Impact Tests with a Free-falling Tup upon Bars measuring 24 mm. by 9 mm. in Diameter taken Transversely.	
		Thickness	Tensile Strength		Number of Blows borne without Breaking.	Bending Angle.
						deg.
A	1·27	50·1	68·7	15	26	70
		50·1	69·0	15	26	71
B	1·50	49·5	69·7	20	26	74
		50·1	70·7	18	Broke at 23rd blow	82
A'	7·95	50·8	67·4	10	Broke at 16th blow	105
		49·5	66·1	9	Broke at 18th blow	107
B'	11·88	52·1	68·1	12	Broke at 12th blow	132
		51·5	68·1	12	Broke at 16th blow	119

III.

Results relative to the influence of hot-working on the properties of steel appear to be pretty easily ascertainable, taking into account the new data as to the heterogeneity of steels which the new cupric reagents recently employed by Drs. Rosenhain and Stead and Mr. Le Chatelier enable us to obtain. Fig. 7 is a reproduction of preparations obtained by this process, and shows that the dendrites formed during the solidification of the steel undergo deformation during rolling, but do not in any way tend to disappear. Subsequent heat treatments do not modify this structure. There is thus found, in juxtaposition in the steel, two series of elements corresponding with two different compositions [the dendrites of the initial solidification and the filling (*ciment de remplissage*)], and the mechanical properties of which differ. Generally speaking, the filling which has solidified latest will contain a higher proportion of impurities and will be less ductile than other portions of the metal.

Fig.6.



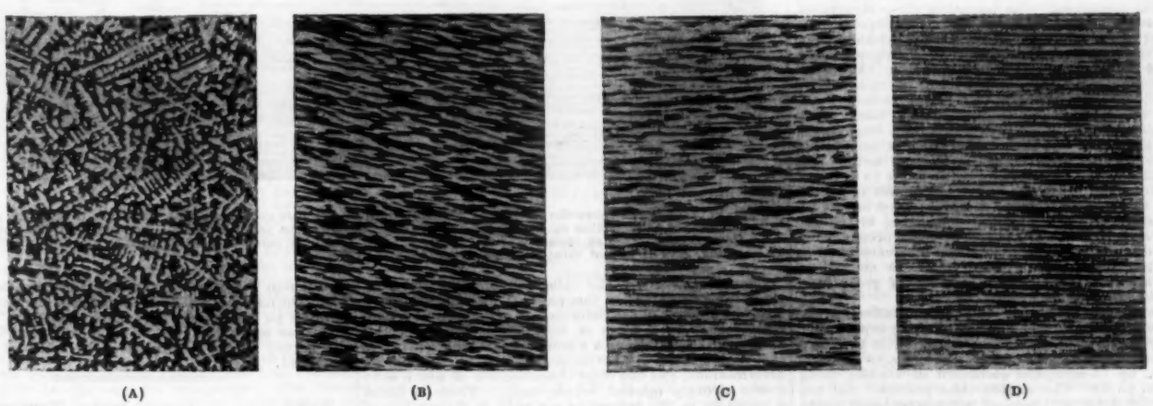


FIG. 7.—Deformation of the dendrites of the original ingot by successive rollings.

In molten steel the two elements are distributed more or less uniformly, and, except in certain portions of the ingot, do not present any marked orientation; although it must not be forgotten that the ingot is far from being isotropic. In any case rolling will produce very pronounced heterotropy, which, according to circumstances, may increase or hinder that already pre-existing in the ingot, but which will always tend completely to predominate over it once deformation has reached a certain amount. Rolled steels will therefore always present a structure composed by the juxtaposition of elements practically rectilinear and parallel with the direction of rolling, and the transverse dimensions of which will be the more reduced, according as, other things equal, the coefficient of working has been greater.

It will easily be conceived that the distribution of the alternating elements along the axis of a tensile test-piece or in the notch of an impact test-piece varies with the direction of the bar in relation to the bloom and with the amount of drawing-down undergone by this bloom, and that these differences in distribution will strongly induce variations in the mechanical properties. Without attempting to follow in detail the application of the foregoing to an actual instance, it will be seen that, the relative proportions of the two elements being fixed and determined by the nature of the steel, the differences between test-pieces may be characterised by the length of the heterogeneous elements juxtaposed along the length of an axis. It may be conceived likewise that the tensile strength must be determined by the nature of the elements, and not by their dimensions, which are, therefore, without marked influence on the breaking stress, and that this influence on the general deformations must also be but slight. In highly-localised deformations, however, such as those which precede breaking, the dimension of the element which undergoes this deformation plays a highly important part, inasmuch as the breaking occurs once this element has reached its limit of deformation. This limit will be the sooner reached the smaller the dimension of the element, other things, that is, equal; and that, consequently, the metal will have been the more drawn out for a given orientation of the test-piece, or that for a given drawing-down the bar in question shares more closely the direction of the elongated elements. These two conditions will lead to a decrease in the contraction of area and in the angle of impact-bend prior to breaking, in notched bars, and hence a diminution in the work of rupture they can withstand.

In Fig. 8 there are reproduced (enlarged to double natural size) the structures observed in the impact test bars tested in the second experiment described in Part I.

The photographs A and B correspond with the longitudinal and transverse bars respectively taken after drawing-down to 1.7. It will be seen that the dendrites of the first solidification have been but little deformed, and that, as a result, their directions differ but little, and it may be foreseen that the work of rupture attained will differ little between them. The actual figures obtained were 7.5 (longitudinally) and 6 (transversely). On the other hand, after drawing down to 6.1 the orientation is very clearly marked, as shown by the photographs C (longitudinal test bar) and D (transverse test bar). The differences in impact figures observed correspond with these differences in structure, namely, 9.5 for the longitudinal bars and only 3.5 for the transverse bars. In Fig. 9, annexed, is shown the structure of the two tensile test-pieces corresponding with a coefficient of working of 6.1, tested in the first experiment of Part I, and the outer appearances of which are shown in Fig. 5, page 313.

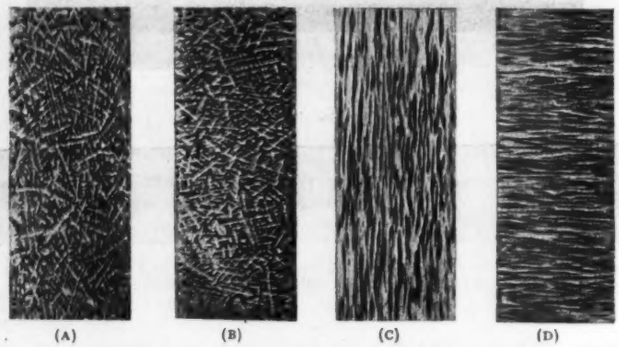
From what has been said, it will be possible to appreciate—at any rate qualitatively—the influence of working, at any point within a piece, from the relation between the dimensions and direction of the less resistant (or more particularly the more ductile) structures, and the test-pieces to be employed in ascertaining the mechanical properties. The nature of these structures, their dimensions, and their directions will depend upon the conditions of casting of the original ingot and on the different deformations they may have undergone in the course of working. It will be seen from this, even better than from what has been said in the first part of this paper, how illusory it is to attempt to deduce the influence of working from a simple formula based solely on the initial and final outward shapes of a forging. It will, in particular, be understood how a number of successive forgings which restore a block of metal to its original dimensions after having subjected it to different deformations (deformations which will vanish in all the ordinary formulæ relating to working) may have profoundly affected the mechanical properties, or, to say the least of it, the relative values of these properties in different directions. Such conditions intervene even in the simplest forging operations, when the method of working involves intermediate shapings of great local variety, which is nearly always the case.

The considerable influence of the orientation of the structures is well brought out in the following experiment.

A piece of the semi-hard ingot employed in the third experiment in Part I, was reduced, by rolling, to a section of 75 mm. by 75 mm., the coefficient of working being thus equal to 13. The section thus produced did not allow of the different types of test-pieces being taken both longitudinally and transversely. Only notched bar test-pieces were therefore taken, but, in lieu of longitudinal and transverse bars, two others were taken at angles of 70 deg. and 45 deg. with the axis, all taken from the same longitudinal cut. Fig. 10 shows the lay of these bars; there has been reproduced, at a magnification of four times, the structure of the metal, as shown by etching with the cupric reagent, so as to bring out the orientation of the fracture surfaces in relation to the structures of the metal.

The impact tests, carried out after quenching and annealing the bars, gave the following results:—

No. of Bar.	Angle of Notch with Direction of Rolling. Deg.	Work absorbed on Rupture.
1	0	1.30
2	20	1.50
3	45	3.40
4	90	13.50



(A) (B) (C) (D)

FIG. 8. These photographs show the appearances obtained on etching the notched surfaces of one of the pieces from four different notched bars, with cupric reagent.

The test piece A was cut longitudinally, and the test piece B transversely from the same billet, which had been drawn down 1.7. The dendrites of the original solidification are but little deformed, and the impact values obtained are in the neighbourhood of one another (7.5 for A, and 6.0 for B). The test piece C (longitudinal) and D (transverse) were taken from the same billet which had been drawn down 6.1. The orientations due to rolling are very marked, and the impact values (9.5 for C and 3.5 for D) differ greatly.

(A) (B)

FIG. 9. These photographs show the results of etching sections across the diameters of two of the test bars shown in Fig. 5, with cupric reagent This etching has brought out the structure, which corresponds with the type of fracture.

(A) Longitudinal bar. Normal fracture and contraction. (B) Transverse bar. Oblique fracture without contraction.

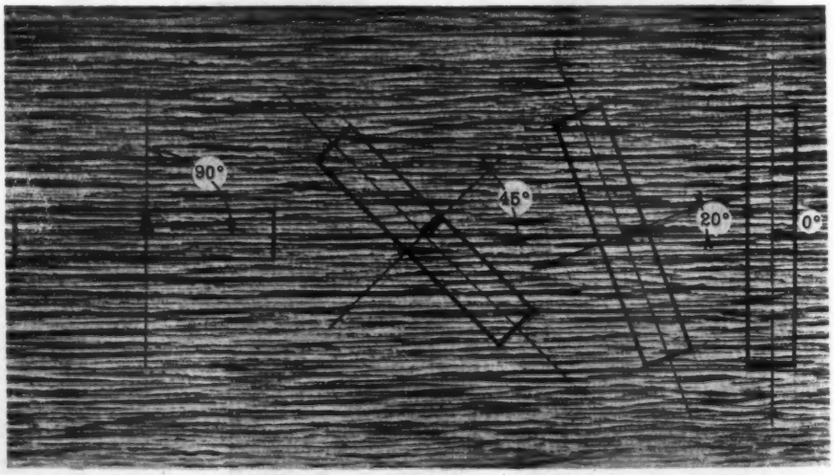


FIG. 10. This figure shows the method by which notched-bar test bars were taken, in a rolled bar, to show the marked influence of the direction on the impact value. The test piece, the notch of which is perpendicular with the direction of rolling, gave an impact value of 13.50; the test piece, the notch of which is parallel with the direction of rolling, gave an impact value ten times lower, namely, 1.30.

Conclusions.—From the collection of facts and considerations contained in this paper it may be concluded that the amount of the deformation undergone at a high temperature by a block of steel affects the properties of the metal according to a complex law which involves the initial state of the ingot and all the subsequent deformations, and the chief characteristic of which is to create strongly marked heterogeneity. There is found a variation in the properties not only of degree, but of nature as well, according as the direction of the test bars employed varies in relation to the piece whence they are derived. The total effect is far from being in the nature of a general improvement, as would appear to be looked for whenever, in specifications, a minimum amount of working is prescribed. It would appear, on the contrary, that the result is more injurious than useful, and that, consequently, the specification of a maximum deformation would be more logical. It is impossible to fix a general rule. For pieces working under transverse stresses, such as guns, drawing-down lengthwise has undoubtedly an injurious effect, at any rate in mechanical tests required in inspection, and it would be better to reduce it to as little as possible. For steel parts of more complex shape the problem differs in each specific case, and it would appear that the only guidance is by studying the conditions beforehand. The designer, who knows how he wants the part he has designed worked, should construe his ideas into deciding the localities from which test-pieces should be taken corresponding with predetermined conditions; these test-pieces should be taken in different directions if these be the conditions under which the material will be employed, and the metallurgist, in order to meet with these fixed conditions, should in each case select the type of ingot to be employed and the nature of the deformations to which it is to be subjected.

WRECK OF A LARGE STEAM TURBINE.—Some particulars are given in *Power* of the wreck of a 35,000-kw. steam turbine at the North-West Power Station, Chicago. The machine was designed to run at 1,500 r.p.m., and was having its emergency governor tested when the smash occurred. The speed had reached 10 per cent. in excess of the normal when something gave way inside the low-pressure casing, which was rent asunder by the flying pieces. Part of the turbine are said to have gone through the roof of the power-house. The entire unit is said to be completely ruined.

THE TENACITY OF BASIC STEEL.

*The Influence of Some Elements on the Tenacity of Basic Steel, with a New Formula for Calculating the Maximum Load from the Composition.**

By ANDREW MCWILLIAM, D.Met., A.R.S.M. (Metallurgical Inspector, Government of India, Indian Munitions Board).

FOR many years before coming to India the author was mildly interested in formulæ for calculating the tensile strength of steels of known composition and normal treatment, but found them all unsatisfactory for use on the very varied series and high range of tempers made at the University of Sheffield as well as on the general line of those produced commercially in steelworks in Sheffield.

On coming to India he felt the desirability, in connection with the work of inspection, of obtaining a formula which would give reasonably correct results within the range of the British Standard Specifications for structural steels, that is, 28 tons to 32 tons per square inch maximum (since altered to 28 tons to 33 tons), and this was fairly easily accomplished. When steels much above the British standard in tenacity came to be required in Sakchi the empirical formula broke down, and a strenuous endeavour was made to obtain one on a rational basis. It was felt that by closely estimating the tenacity of pure iron and the effects of the various elements present, and of their influences on one another, it should be possible to evolve a formula that would agree with the tensile strength obtained on the testing machine within about 1 ton for steels within the limits of the British Standard Specification for structural steels, and within about 2 tons for tempers above, say, 40 tons per square inch. Assuming results for the various elements that were fairly well established for the lowest tempers, and deducting the totals from tests of very mild material, the strength of absolutely pure iron was estimated to be about 38,000 lb., or 17 tons per square inch.

In all the calculations that follow the sections of the steel bars are assumed to be of the order of 1 in. round, or other sizes that would not differ much from these in tenacity, and the condition of the materials to correspond with that represented by the term "normalised."† In stating the effect of any element of the tenacity of the steel, the unit of the element will be taken at 0.01 per cent.

It seemed to be fairly generally recognised that phosphorus adds about 1,000 lb. per unit, and this effect was accepted in the preliminary series of calculations, which pointed to the figure 100 lb. as being nearest to the effect of manganese in the lower tempers. The silicon in the steels was so low that it could be ignored, but afterwards was estimated to be about 120 lb., and as sulphur is generally considered, and from the mode of its occurrence in the steel would be expected to have very little effect on the tenacity, its influence was ignored, especially as the sulphur in the steels was generally below 0.03 per cent.

In a series of carefully tested steels of from 20 per cent. to 26 per cent. carbon this left the influence of the carbon at about 800 lb. per unit, so the first attempted rational formula for steels within the older British Standard of 28 tons to 32 tons was:

Maximum load in lbs. per square inch of original section = 38,000 + 800 C + 100 Mn + 1000 P.

When basic steels were made of from 33 tons to 50 tons or 60 tons per square inch the formula was tried, and found, as with others, to fail. The problem of obtaining the separate effects of the added elements is a most complicated one, and is made still more difficult by the fact that results obtained in works practice on the testing machine, even when the test-piece itself is analysed, vary more than the differences that one would care to allow between the general results of the calculations from the compositions and those obtained by testing. This being so, the only way seemed to be to calculate hundreds of tests so as to eliminate so far as possible the effect of the variations in the test results. It is almost impossible to be certain, owing to these variations, that the correct value has been assigned to each of the elements present, especially considering the different effects of the elements in the presence of one another; but one comforting result of the hundreds of calculations made is, that the elements seem to preserve their individual effects much more strongly than might have been supposed.

In searching for a reason why the formula that gave correct results round 0.2 per cent. carbon gave results much too low at, say, 0.5 per cent. carbon, it was thought that as the carbon would be present in the form of pearlite to which the added strength was due, the more pearlite present the greater effect the carbon would have per unit on the tenacity of the mass, and that as the manganese influenced the nature of the pearlite its influence would increase with increasing proportions of pearlite. Another long series of calculations was then made on the ordinary results obtained day by day, supplemented by as many as possible from our records, with the result that the effect on tenacity per unit of carbon present was shown to increase with the amount present, and that the same appeared to be the case for manganese. The figures obtained were at 0.2 per cent. carbon about 800 lb. per unit of carbon, rising apparently quite regularly to somewhere about 1,000 lb. at 0.7 per cent. carbon, although the upper figure is not so reliable as the lower, owing to the very much smaller number of tests on which it has been based. The manganese in the same range seemed to vary in effect from about 100 lb. at 0.2 per cent. carbon to 200 lb. at 0.7 per cent. carbon. These are shown graphically in Fig. 1. Later from published and other records, the silicon used was estimated to add about 120 lb. per unit, so the formula is now

M.L. = 38,000 + [800 + 4 (C − 20)] C + 120 Si + [100 + 2 (C − 20)] Mn + 1000 P.

M.L. representing the maximum load in lbs. per square inch of original section. This formula has stood the test of trial wonderfully well. Even with the higher silicon shell steels it has given good results.

On reading Dr. Stead's paper of September, 1916,* it was decided to extend these results and put the matter in shape for a paper to the Institute, in the hope that the formula would be tested by many of the members, criticised in detail, and that ultimately, if found defective to any marked degree, a new one would be obtained that would apportion the correct effect to each element. One's own steels are apt to run in lines, and do not show the defects in a formula which might be obtained when many makers and experimenters test it on their results. To simplify the calculations a table is appended giving the effect by the formula of each amount of carbon from 0.10 per cent. to 0.75 per cent., allowing extrapolation from 0.2 per cent. to 0.1 per cent., and from 0.7 per cent. to 0.75 per cent. There seems little doubt that not far

Fig. 1. EFFECTS OF 0·01 PER CENT OF CARBON AND OF MANGANESE RESPECTIVELY ON MAXIMUM LOAD IN LBS PER SQUARE INCH OF ORIGINAL SECTION.

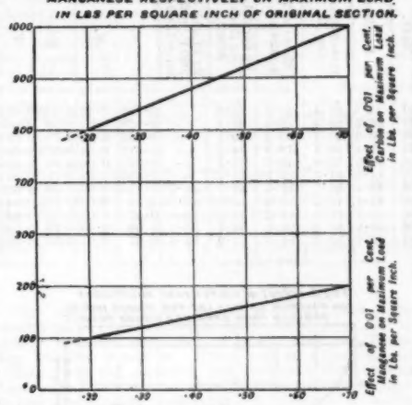
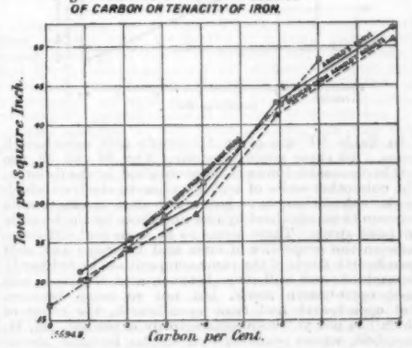


Fig. 2. CURVES SHOWING INFLUENCE OF CARBON ON TENACITY OF IRON.



above 0.75 per cent. the value per unit of carbon begins to decrease. So far the formula had sufficed for our own needs, but in preparing the material for publication it was felt that it should be tested on reliable published results.

Turning first to Arnold's classical carbon series of pure crucible steels, it was found that for his steels within the range, namely, No. 1 with 0.08 per cent., No 1¼ with 0.21 per cent., No. 2 with 0.38 per cent., No. 3 with 0.59 per cent. carbon, the formula gave for

No. 1, 20.8 tons compared with 21.39 tons, or 47,914 lb. by test.
No. 1¼, 25.8 tons compared with 25.39 tons, or 56,874 lb. by test.
No. 2, 33.3 tons compared with 29.94 tons, or 67,066 lb. by test.
No. 3, 43.8 tons compared with 42.82 tons, or 95,917 lb. by test.

These results are in fairly close agreement, unless for No. 2. It is noted that between 1 and 1¼ the carbon adds 689 lb. per unit to the tenacity, between 1¼ and 2, 600 lb., between 2 and 3, 1,374 lb.; or, again, 1 to 1¼, 689 lb.; 1 to 2, 638 lb.; 1 to 3, 941 lb.; or, allowing for the slight differences with other elements present, from 1 to 1¼, 648 lb.; 1¼ to 2, 596 lb.; 2 to 3, 1,329 lb.; or 1 to 1¼, 648 lb.; 1 to 2, 618 lb.; 1 to 3, 916 lb. It is interesting to note that, according to these calculations, the tenacity of pure pearlite and normalised would be almost exactly 51 tons per square inch, as given by eliminating the calculated effect of the impurities present.

The author's results were obtained by trial and error, by calculation on each day's work, and he had not thought of comparing the results with Arnold's series during the trials. Since the attempt to get a formula on a rational basis began the same constant of 38,000 lb. or 17 tons for the iron has been used. The first formula of 800 C + 100 Mn + 1000 P served well until we began to make and test steels above about 0.4 carbon, and then it was found that results near enough to the test results could not be obtained by the formula, but were given by raising the carbon figure to 900 and the manganese figure to 150. Then above about carbon 0.6 per cent. it was found necessary to raise these figures again to 1,000 and 200 respectively. As no sign of an abrupt change was detected, it was then decided to take the even change from 800 C. at 0.2 to 1,000 C. at 0.7, as already stated.

TABLE I.—*Effect of Carbon from 0.1 per cent. to 0.75 per cent. on the Tenacity of Basic Steel. The Tenacity of Pure Iron being taken at 38,000 lb. or 17 tons.*

Carbon per Cent.	Lb. per Sq. In.	Tons per Sq. In.	Carbon per Cent.	Lb. per Sq. In.	Tons per Sq. In.	Carbon per Cent.	Lb. per Sq. In.	Tons per Sq. In.
0·10	7,600	3·4	0·32	27,036	12·1	0·54	50,544	22·6
0·11	8,404	3·8	0·33	28,016	12·6	0·55	51,700	23·1
0·12	9,216	4·1	0·34	29,004	13·0	0·56	52,864	23·6
0·13	10,036	4·5	0·35	30,100	13·4	0·57	54,036	24·1
0·14	10,864	4·9	0·36	31,104	13·9	0·58	55,216	24·7
0·15	11,700	5·2	0·37	32,116	14·3	0·59	56,404	25·2
0·16	12,544	5·6	0·38	33,136	14·8	0·60	57,600	25·7
0·17	13,396	6·0	0·39	34,164	15·3	0·61	58,804	26·3
0·18	14,256	6·4	0·40	35,200	15·7	0·62	60,016	26·8
0·19	15,124	6·8	0·41	36 244	16·2	0·63	61,236	27·3
0·20	16,000	7·1	0·42	37,296	16·7	0·64	62,464	27·9
0 21	16,884	7·5	0·43	38,356	17·1	0·65	63,700	28·4
0·22	17,776	7·9	0·44	39,424	17·6	0·66	64,944	29·0
0·23	18,676	8·3	0·45	40,500	18·1	0·67	66,196	29·6
0·24	19,584	8·7	0·46	41,584	18·6	0·68	67,456	30·1
0·25	20,500	9·2	0·47	42,676	19·1	0·69	68,724	30·7
0·26	21,424	9·6	0·48	43,776	19·5	0·70	70,000	31·3
0·27	22,356	10·0	0·49	44,884	20·0	0·71	71,284	31·8
0·28	23,296	10·4	0·50	46,000	20·5	0·72	72,576	32·4
0·29	24,244	10·8	0·51	47,124	21·0	0·73	73,876	33·0
0·30	25,200	11·3	0·52	48,256	21·5	0·74	75,184	33·6
0·31	26,164	11·7	0·53	49,396	22·1	0·75	76,500	34·2

In Fig. 2 these results are plotted for comparison. The full line shows Arnold's carbon series normalised, the dotted line representing the same series with the total values for the small quantities of impurities present eliminated. The curved line shows the carbon values as obtained by a long series of trial and error calculations on ordinary commercial steels, the composition of the test-pieces used, in cases of special interest for the curve, being checked by analyses of the test-pieces.

One point to be determined is whether in the commercial steels there is a sudden change in the value of the carbon between 0.38 and 0.59—a region containing the half pearlite, half ferrite steels, or whether the effect of the carbon is represented by a smooth curve. The author's calculations so far indicate a smooth curve between 0.2 per cent. and 0.7 per cent. carbon, although the method is not so apt to detect a sudden change of direction in the curve as the direct method of experiment.

In connection with any effect of phosphorus one instinctively turns to Stead's results, and taking his well-known series of three with 0.041 per cent., 0.302 per cent., 0.509 per cent. phosphorus, it was found that, allowing for the effects of the other elements present, the phosphorus in the 0.041 per cent. sample was represented by 880 lb., in the 0.302 per cent. by 620, and in the 0.509 per cent. by 550 lb., whilst in Arnold's 1.37 per cent. phosphorus steel the phosphorus only added about 150 lb. per unit to the tenacity. At first sight these results do not seem to lend much countenance to the estimate of 1,000 lb. per unit of phosphorus for steels containing up to 0.03 per cent. phosphorus, but on plotting them as a curve they are seen distinctly to support the view and to point to the correctness of the usual estimate of the value of phosphorus, which although it has been taken in all these steels at 1,000, may be 900 for those containing 0.03 per cent. to 0.06 per cent. The value of silicon has been gathered from published results, such as Baker's. For Arnold's silicon steel the formula gives 31.6 tons compared with 31.7 tons by test.

The author would like his friends, whilst critically examining each part of the formula, to pay particular attention to the manganese, as there most of the differences in opinion seem to be with reference to this element. As we are attempting to obtain general agreement in a series of, say, a day's work within 1 ton up to 33 tons with only an occasional member of the series beyond, and within 2 tons for higher tempers, and 0.03 per cent. carbon represents over 1 ton in tenacity, it is not much use taking special notice of divergencies unless the test-piece is analysed, as distinct from the ladle sample. In Arnold's 1.29 per cent. manganese steel the manganese adds 150 lb. per unit to the tenacity.

It is interesting to apply the formula to some of the published lists of tests, so it has been applied to Harbord's basic Bessemer and basic open-hearth steels, as shown in Tables II. and III. In the mean of experimental and collected results, assuming 0.6 manganese and 0.5 phosphorus and silicon negligible, the carbon per cent. recommended for 30 tons gives 30.8 by the formula; for 35 tons, 36.6; for 45 tons, 44.3; and for 50 tons, 49.6.

The agreement in the basic Bessemer series is quite good, the mean of the set by calculation being 33.8 and by test 34.1. The mean of those between 0.2

* Paper read before the Iron and Steel Institute, Thursday, September 12, 1918.

† "Influence of some Elements on the Mechanical Properties of Steel," *Journal of the Iron and Steel Institute*, 1916, No. II.

and 0.7 is still nearer, being 38.6 by calculation and 38.5 by test. The agreement in the basic open-hearth series is not so good, the means being 37.6 tons by calculation and 35.5 by test. It would not be feasible to give the many hundreds of tests on which the calculations have been made, but a few have been gathered at random and are given in Table IV.

TABLE II.—*Harbord's Basic Bessemer Series.*

Mark.	As Received.	Heated to 620 Deg. C.	Means of 2 and 3.	By Formula.	C.	Mn.	P.
16	23·5	23·4	23·5	22·4	0·07	0·345	0·044
17	27·5	27·7	27 6	25·3	0·09	0·475	0·082
18	25·5	24·4	25·0	24·9	0·10	0·435	0·066
19	26·5	25·2	25·9	25·6	0·11	0·481	0·069
20	28·8	28·8	28·8	27·0	0·12	0·665	0·076
21	31·5	29·8	30·7	30·7	0·22	0·513	0·074
22	34·0	33·9	34·0	32·7	0·24	0·520	0·099
23	36·0	33·9	35·0	35·5	0·30	0·74	0·076
24	38·7	36·3	37·5	39·2	0·36	0·825	0·070
25	39·5	37·8	38·7	39·9	0·378	0·855	0·068
26	40·1	38·2	39·2	38·5	0·381	0·825	0·040
27	41·5	41·2	41·4	40·0	0·38	0·955	0·065
28	43·2	42·6	42·9	43·7	0·44	0·925	0·063
29	48·0	46·4	47·2	47·0	0·503	0·90	0·065
Means	34·6	33·5	34·1	33·8			

TABLE III.—*Harbord's Basic Open-Hearth Series.*

Mark.	As Received.	Heated to 620 Deg. C.	Means of 2 and 3.	By Formula.	C.	Mn.	P.
41	24·5	24·2	24·4	25·1	0·12	0·40	0·051
42	28·5	27·4	28·0	28·7	0·20	0·51	0·052
43	26·8	25·5	26·2	29·8	0·23	0·45	0·054
44	37·8	36·3	37·1	39·2	0·35	0·853	0·077
45	34·0	32·0	33·0	36·7	0·355	0·49	0·071
46	34·4	32·1	33·3	36·9	0·36	0·90	0·018
47	35·0	33·8	34·4	37·6	0·37	0·66	0·054
48	36·3	35·2	35·8	38·7	0·388	0·625	0·040
49	37·0	35·5	36·3	39·1	0·42	0·575	0·041
50	38·6	36·3	37·5	40·7	0·43	0·61	0·058
51	42·5	40·1	41·3	41·7	0·45	0·72	0·060
52	44·0	42·6	43·3	45·2	0·502	0·68	0·064
53	51·5	49·2	50·4	51·5	0·603	0·71	0·070
Means	36·2	34·7	35·5	37·6			

TABLE IV.—*Indian Basic Open-Hearth Steels.*

No.	Section.	By Test.	By Formula.	C.	Si.	Mn.	P.
1	¾-in. rd. ..	23·5	23·5	0·13	—	0·34	0·016
2	1-in. rd. ..	26·4	25·3	0·14	—	0·53	0·033
3	¾-in. rd. ..	26·4	25·5	0·17	—	0·45	0·011
4	1-in. rd. ..	26·8	26·5	0·18	—	0·53	0·021
5	4-in. by ¾-in. f.	27·5	28·1	0·21	—	0·69	0·008
6	10 in. by 5-in. b.	28·2	28·0	0·22	—	0·60	0·008
7	1¼-in. rd. ..	28·0	28·7	0·23	—	0·57	0·016
8	1¼-in. sq. ..	28·4	34·0	0·25	—	0·69	0·022
9	¾-in. rd. ..	31·8	30·6	0·25	—	0·64	0·030
10	¾-in. rd. ..	31·8	31·4	0·26	—	0·56	0·047
11	1-in. rd. ..	32·3	31·6	0·27	—	0·71	0·023
12	1-in. sq. ..	29·1	29·3	0·28	—	0·58	0·011
13	¾-in. sq. ..	32·2	32·4	0·29	—	0·74	0·015
14	10-in. by 5-in. b. ..	34·4	34·1	0·30	—	0·74	0·042
15	¾-in. rd. ..	32·9	32·5	0·31	—	0·56	0·017
16	10-in. by 5-in. b. ..	35·3	35·6	0·32	—	0·82	0·046
17	3¾-in. rd. ..	36·5	34·8	0·34	0·06	0·66	0·018
18	1-in. sq. ..	35·3	35·6	0·37	—	0·66	0·010
19	1-in. sq. ..	38·5	38·0	0·41	—	0·66	0·015
20	5-in. rd. ..	39·6	39·4	0·42	0·07	0·72	0·021
21	1-in. sq. ..	37·6	38·9	0·44	—	0·57	0·012
22	5-in. rd. ..	40·9	41·8	0·44	0·08	0·82	0·010
23	5-in. rd. ..	44·6	45·0	0·48	0·07	0·92	0·030
24	Imported basic rail..	48·1	47·4	0·53	0·04	0·80	0·054
25	2-in. sq. ..	45·5	47·9	0·57	—	0·73	0·019
26	—	54·5	55·2	0·66	0·15	0·75	0·046
27	1-in. oct. ..	52·5	53·0	0·67	0·03	0·69	0·037
28	¾-in. rd. .. N	54·0	54·0	0·69	—	0·62	0·019
29	¾-in. rd. .. N	54·5					
30	¾-in. rd. .. N	59·2	58·2	0·73	—	0·67	0·029
31	¾-in. rd. ..	63·7	61·0	0·75	0·03	0·80	0·050
32	¾-in. rd. .. N	64·6					

TABLE V.—*Acid Bessemer Series of McWilliam and Barnes.*

Mark.	As Received.	Normalised.	Means of 2 and 3.	By Formula for Basic Steels.	By 38,000 + 1,000 C. + 200 Mn. + + + 1,000 P.	C.	Mn.	P.
a	25·9	24·8	25·4	25·5	29·1	0·10	0·56	0·06
b	35·8	34·3	35·1	33·1	37·8	0·27	0·68	0·06
c	40·9	40·8	40·9	35·3	40·8	0·29	0·92	0·06
d	39·9	39·3	39·6	35·5	39·9	0·32	0·67	0·06
e	46·6	48·1	47·4	42·3	47·3	0·44	0·90	0·06
f	52·2	52·3	52·3	46·8	50·2	0·50	0·92	0·06
g	59·0	59·4	59·2	58·9	58·9	0·70	0·90	0·06
h	64·2	65·4	64·8	62·4	61·3	0·75	0·92	0·06

Although the formula is intended for basic steel, it is worth applying it to acid steels to see the nature of the results. As an aid to inspection it has been helpful. Another of the causes that led to the search for a formula was the possibility of being able to distinguish between acid and basic steels by comparison of the test results with analyses of the test-pieces, as now, with high silicon alloys, simple analysis can no longer distinguish between steels made by the two processes. The author's Sheffield friends who long for a method that will enable the purchaser to know that he is getting acid steel, and our Middlesbrough friends, who are so proud of their basic steel that they would be shocked at any one mistaking it for acid, will be equally disappointed that in the lower and more usual tempers the differences do not seem to be sufficient to be quite characteristic.

In Table V. the results by the formula for basic steels on the acid Bessemer series of McWilliam and Barnes are shown, and for comparison those by the formula M.L. = 38,000 + 1,000 C. + 200 Mn. + 1,000 P., which is the formula for basic steels as it stands at 0.7 per cent. carbon. The tenacity of steel (*a*) at 0.10 per cent. carbon agrees with the basic steel formula, steel (*b*) with 0.27 per cent. carbon agrees with values for carbon and manganese of 900 lb. and 150 lb. respectively, and the steels from 0.29 per cent. to 0.7 per cent. carbon agree fairly well with the formula in column 6, whilst (*b*), the 0.75 per cent. carbon steel, would require 1,110 lb. per unit of carbon in the formula to agree with the test result.

TABLE VI.—*Harbord's Acid Open-Hearth Series.*

Mark.	As Received.	Heated to 620 Deg. C.	Means of 2 and 3.	By Formula for Basic Steels.	By 38,000 + 1,000 C. + 200 Mn. + 1,000 P.	C.	Si.	Mn.	P.
30	25·5	25·4	25·5	25·6	—	0·132	0·03	0·400	0·055
31	26·2	26·8	26·5	26·1	—	0·128	0·02	0·53	0·058
32	30·3	30·2	30·3	29·1	—	0·183	0·04	0·71	0·052
33	33·4	33·1	33·3	34·3	—	0·311	0·04	0·575	0·052
34	37·0	35·6	36·3	37·7	—	0·370	0·06	0·80	0·029
35	43·6	41·7	42·7	41·1	—	0·436	0·04	0·71	0·041
36	49·5	43·7	46·6	41·7	44·7	0·45	0·07	0·68	0·038
37	45·8	44·1	45·0	44·0	47·1	0·50	0·05	0·672	0·041
38	50·4	47·9	49·2	49·0	50·8	0·57	0·05	0·71	0·047
39	60·8	56·4	58·6	54·7	55·2	0·66	0·05	0·70	0·055
40	55·7	52·2	54·0	54·9	54·6	0·67	0·07	0·60	0·054

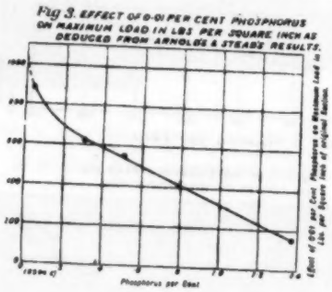


Fig 3. EFFECT OF 0·01 PER CENT PHOSPHORUS ON MAXIMUM LOAD IN LBS PER SQUARE INCH AS DEDUCED FROM ARNOLD & STEARS RESULTS.
Phosphorus per Cent

In Table VI. are given Harbord's acid open-hearth series. All these steels, excepting Nos. 36 and 39, are within reasonable limits of those obtained by the formula. The only other series of acid open-hearth steels on which similar calculations have been made show similar results between those obtained by test and those by the formula for basic steels. There seems to be some real difference between the properties of even acid Bessemer and acid open-hearth steels of the same composition, as ordinarily determined, and still more between acid Bessemer and basic open-hearth steels, but not so much between acid open-hearth and basic open-hearth, the cause of which has not yet been satisfactorily explained. H. H. Campbell, whose researches on similar formulæ are so well known, remarks:* "The results indicate that the metalloids have different quantitative effects upon acid and basic steels. Now, if acid steel does not follow the same law as basic steel,' then they are not the same, and if they are not the same, it is possible that one is better than the other, a possibility that is vigorously denied by some people."

Summary.—On the publication of Dr. Stead's paper in September, 1916, the author felt that as a contribution to the attempt to determine more and more closely the influence of each of the elements on steel, it would be worth preparing for publication his own results which he had obtained as a help in his ordinary work as well as for their metallurgical interest. All these formulæ should have as their constant the strength of pure iron. The formula used at present for sections that would give results near to those obtained on 1-in. round bars normalised is given with a table of the effect of carbon between 0.1 and 0.75 for ease in calculation. The results of the application of the formula to certain series of steels are shown.

A bibliography on the influence of some elements on the mechanical properties of steels was given by Dr. Stead in September, 1916. The papers by McWilliam and Barnes on Heat Treatment were given, excepting the one on "A Heat Treatment Study of Bessemer Steels," to which it is well that students should refer, as it shows what can be done with first-class English acid Bessemer steels, for comparison with results on more costly material.

* "Manufacture and Properties of Iron and Steel," p. 23.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

A Practical Coal-Saving Scheme.—A practical measure for the economising of coal and gas in these times of national necessity has been introduced by one of Sheffield's most important cutlery concerns, who have posted a notice in their works offering for every ton of coal saved during the coming winter as compared with the amount used last winter, dating from September 1 to March 1, the sum of 1*l.* For all gas saved in comparison with last winter an equivalent sum will be paid. The money will go into the Works Club funds and be equally divided among the workpeople, male and female alike. The firm state that this offer is made, not because of the increased prices of these commodities, but because, at any moment, it is a national necessity.

Iron and Steel.—Trade conditions generally do not show any marked signs of improvement, the numerous restrictions tending to hamper any business not immediately connected with munition construction. Engineering houses who formerly did a large export trade in agricultural implements and machinery are prohibited from shipment even to neutral countries, and as several of these, notably Holland, have embarked on a large scheme of agricultural expansion, connections which have existed for generations have been broken, and customers are said to have been frequently driven into the hands of Swedish and German manufacturers. So far as munitions and supplies for the army are concerned the great influx of American troops to this country and France has led to an enormous increase in the demand for stores and equipment. Orders for cutlery of every description, tools, machinery, saws, spades, shovels and other agricultural and trenching implements have been of overwhelming volume. The call for shell and gun steel continues heavy. Open-hearth furnaces, both acid and basic, are working at full pressure, but in no degree overtake the demand, with the result that the whole production immediately passes into consumption. The reports from crucible steel houses are hardly as satisfactory. Furnaces have largely increased in number since the war, and have the consumption well in hand. Heavy stocks have been accumulated of aircraft steel, of which makers state there is a sufficiency to meet the demand for many months ahead. In scrap, the fact that the Government has largely taken business out of merchants' hands, and are dealing direct with the consumer, has not tended to facilitate business, there being reports of considerable congestion at some works and scarcity at others. Dissatisfaction is also expressed at the new maximum prices of cast-iron scrap. Heavy machinery scrap formerly worth 7*l.* a ton has been fixed at a maximum of 5*l.* a ton. Complaints are also rife at the allowance of 5*s.* per ton for breaking up large pieces of metal, which, with wages at their present high level, is said to be inadequate.

South Yorkshire Coal Trade.—The output of the past week has been of a somewhat more satisfactory character, but the demand is pressing, and arrears far from being made up. Stocks are non-existent, the collieries, after supplying Government and other allocated requirements, have no supplies for the open market. Steams of all descriptions are in active request, and producers have the greatest difficulty in meeting demands. This applies to all sections of industry, and is aggravated so far as the home trade is concerned by the increased requirements for shipment to Allies, which is now carried on on an increasing scale. The house coal market is unchanged. Supplies are still inadequate. The maximum weekly supply is still being forwarded to the London area, leaving collieries with a minimum tonnage to meet the requirements of other districts. Householders are being urged to stock as much as possible for the coming winter, but find the greatest difficulty in securing the necessary supplies. A steady increasing output from the pits is, however, looked to to relieve the situation. The output of coke in all its branches is readily disposed of at maximum prices. Quotations:—Best branch handpicked, 27*s.* to 28*s.*; Barnsley best Silkstone, 27*s.* to 27*s.* 6*d.*; Derbyshire best brights, 25*s.* to 26*s.*; Derbyshire house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; best large nuts, 22*s.* 6*d.* to 23*s.* 6*d.*; small nuts, 21*s.* 6*d.* to 22*s.* 6*d.*; Yorkshire hards, 22*s.* 6*d.* to 23*s.* 6*d.* Derbyshire hards, 21*s.* 9*d.* to 22*s.* 9*d.*; best slacks, 18*s.* to 19*s.* 6*d.*; seconds, 16*s.* to 18*s.*; smalls, 13*s.* to 14*s.*

THE POLYTECHNIC, REGENT-STREET.—Particulars of courses of instruction to be given at the Polytechnic during the forthcoming session are now issued. The session will commence on Monday, September 30, but the heads and teachers of the various departments will be in attendance each evening during the week beginning September 23, for the purpose of advising intending students in the selection of a course which will be of the greatest help to them in their daily occupations. Applications should be made to the Education Department, 307 to 311, Regent-street, W. 1.

NON-FERROUS METAL INDUSTRY ACT, 1918.—The Board of Trade draw the attention of all companies, firms and individuals holding licences under the Non-Ferrous Metal Industry Act to the fact that these licences do not dispense the holders from complying with the regulations which have been made under the Defence of the Realm Act with respect to the sale or purchase of non-ferrous metals. The necessary permits under these regulations must be obtained from the Ministry of Munitions in respect of any sales or purchases of non-ferrous metals in the same manner as before the licences under the Act were granted.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—In the steel-making industry little material change has taken place within the past few weeks, all the available plant is running at high pressure and production goes on apace. The output of manufactured and semi-manufactured steel is on an enormous scale, and in consequence the accumulated arrears have been considerably reduced. In apportioning the material produced where, and in such quantities as, most urgently required, the Admiralty Superintendent has done much to relieve the tension. Export is practically non-existent, some small shipments to France representing the bulk of the overseas trade at the moment. Prices otherwise than where officially fixed are, to an extent, movable, the urgency of the work being the principal feature. An increase on export rates has taken place recently and ship plates are quoted 16*l.* 10*s.* per ton or thereabouts and angles 15*l.* 10*s.*

Malleable Iron Trade.—The greatest activity prevails and bolt, nut and rivet iron is being turned out in great quantity, while there is also a keen demand for agricultural parts, the bulk of this being directly or indirectly on Government account. Meantime export is restricted to some good contracts on war account for the French Government. "Crown" bars of first quality are now quoted 16*l.* 5*s.* per ton and up, f.o.b., Glasgow.

Scotch Pig-Iron Trade.—The output is heavy, but no stock can be accumulated. Hematite is still scarce, but as better supplies of scrap steel are now available consumers are not in as bad a plight as might have been expected, there is also a continued scarcity of foundry iron, but more forge grade is now forthcoming and thus the pressure is, to an extent, relieved. Firm prices prevail.

The Clyde and Motor Shipbuilding.—Messrs. Barclay, Curle and Co., Limited, Whiteinch, Glasgow, have just completed the construction of the twin-screw, Diesel engined vessel, Glenapp, the largest and most powerful motor vessel which has yet left the stocks. The engines, which have been supplied by Messrs. Harland and Wolff, at their Glasgow establishment, give a total horse-power of 6,600 tons, a fact which demonstrates clearly the progress being made in this direction. In the new vessel electricity is generated by two auxiliary Diesel sets in the engine-room, supplying current for not only the engine-room auxiliaries but all deck machinery, including, of course, the steering gear. Steam for heating, cooking and fire-extinguishing purposes is supplied by a small oil-fuel boiler.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—The demand for large coals continues very active, and collieries are pretty well stemmed. The pressure is naturally heaviest in the case of the better class steam coals, but the market for drys is also good, and deliveries of the more bituminous sorts are better both for export and for inland consumption. Best bunker smalls are firm. The authorities are taking slightly increased quantities for shipment and for the bunkering of requisitioned tonnage. Coking descriptions are relatively scarce, but the dryer smalls are being disposed of with great difficulty, and there is no appreciable reduction in the stocks of the lower-graded qualities. Pitwood is in good supply, and works are being quite comfortably stocked with iron ore.

Newport.—The market for large Monmouthshire coals continues on the whole satisfactory. Black Veins and other semi-bituminous Western Valley coals are in fairly active demand. The more bituminous qualities, too, are finding a steady inland market. Smalls, however, are still on the weak side, and stocks are accumulating rather than diminishing, though an early improvement is anticipated.

Colliery Craftsmen's Demands.—Negotiations are proceeding with the view of securing the adoption of an 8-hours day for colliery craftsmen. When the Executive Council of the South Wales Colliery Enginemen, Stokers and Craftsmen's Association met at Cardiff last Friday, the agents declared that they had the greatest difficulty in preventing the men concerned ceasing work while negotiations were proceeding. After some discussion the council passed a resolution insisting that the demand must be conceded by the Coal Controller by September 30, and failing "a satisfactory settlement" by that date that the National Council of Mine Workers be requested to "advise the rank and file to 'down tools' on October 1."

Coal Rationing in South Wales.—The Monmouthshire and South Wales Coalowners' Association have made an application to the Controller of Coal Mines that the South Wales coalfield be excluded from the rationing scheme for industrial coal, and also to be exempt from the provisions of the Household and Fuel Lighting Order. The text of the Memorandum submitted to the authorities on the subject has not been published.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Pressure for delivery of No. 3 Cleveland pig-iron for home purposes is heavy. The foundries are very busy, but fortunately some firms have a little stock of pig-iron. There is a very plentiful supply of forge quality of pig-iron, but users generally are well bought, and offers to sell either for early delivery or for supply over the remainder of the year meet with little success. Once again there is some ground for complaint as to the truck supply, but, on the whole means of transport are not unsatisfactory. Steamer tonnage available for Scotland is very ample. For home consumption, No. 3 Cleveland pig-iron, No. 4 foundry and No. 4 forge are all quoted 95*s.*, and No. 1 is 99*s.*; and for shipment to France and to Italy, No. 3 is 119*s.* and No. 1 is 124*s.* Clearances to the Allies are well maintained.

Hematite Iron.—As regards East Coast hematite iron, the situation is certainly less stringent. With basic iron and scrap fairly plentiful, these commodities are being more extensively used in the manufacture of steel, with the result that the position is easier. There is no longer difficulty in obtaining adequate supplies to meet all essential home needs, and quantities available for despatch to the Allies are larger. At the same time distribution continues on a most careful system, under strict official supervision. Mixed Nos. are 122*s.* 6*d.* for home use and 147*s.* 6*d.* for export to France and Italy.

Manufactured Iron and Steel.—Notwithstanding the difficulty experienced in securing supplies of fuel, manufactured iron and steel works are kept busily going, and are employed to the fullest extent on home Government and Allied requirements. Output is on a huge scale. Producers of shipbuilding material have their work well in hand. Prices, all round, are very stiff. Principal market quotations stand:—Common iron bars, 14*l.* 15*s.*; best bars, 15*l.* 15*s.*; double best bars, 16*l.* 15*s.*; triple best bars, 17*l.* 15*s.*; iron ship plates, 15*l.* 10*s.*; iron ship angles, 13*l.* 17*s.* 6*d.*; iron ship rivets, 21*l.*; steel ship plates, 11*l.* 10*s.*; steel ship angles 11*l.* 2*s.* 6*d.*; steel boiler plates, 12*l.* 10*s.*; steel strip, 17*l.* 10*s.*; steel hoops, 18*l.*; and heavy steel rails, 10*l.* 17*s.* 6*d.*—all f.o.t. at makers' works. Export prices are not fixed, but they may be given as approximately at about 2*l.* above home rates.

Coke.—Slightly better account is given of the coke position. Though there is still very considerable shortage, the scarcity is less acute, and deliveries to the blast furnaces are more regular. For home use average furnace coke is 33*s.* at the ovens, and low phosphorus quality 35*s.* 6*d.*; whilst for export to neutrals buyers offer 65*s.* to 67*s.* 6*d.* f.o.b. for foundry coke.

THE INSTITUTION OF MUNICIPAL ENGINEERS.—The tenth annual general meeting of the Institution will be held at Southall, Middlesex, on Wednesday and Thursday, October 9 and 10. There will be a presidential address, and the secretary will present a contribution descriptive of the activities and growth of the Institution during the decade 1908–1918. A number of works and installations are to be visited and a paper will be read and discussed on "The Management of Small Sewage Disposal Works."

CORK SLABS FROM CORK WASTE.—The cork refuse from making corks for bottles is ground, mixed with resins, pitch, glue, casein, water glass, and other binders and fillers, and compressed to produce linoleum, and cork slabs and bricks for insulation, &c. Cork slabs of considerable strength may also be obtained by compressing the ground waste at 160 deg. C. or 180 deg. C., without addition of any binding agent, and this was ascribed by J. T. Smith, who patented the process in 1892, to the fact that the cork itself contains a resin which is liberated at high temperature and acts as binding agent. From the researches of H. Ost (*Zeitschrift für Angewandte Chemie*, 1918, page 105), it appears very doubtful, however, that this resin is playing any important part in binding the cork particles. By treating cork with alcohol, chloroform, and also with water (which injures the fibre, however) in a Soxhlet apparatus, Ost extracted about 10 per cent. of fat, resin, tannin, &c., which formed a brittle solid mass, beginning to melt about 150 deg. C. Preparing slabs of extracted and of natural ground cork by compression at 7 atmospheres of the material at 160 deg. for 20 hours, or at 180 deg. for 3 hours, Ost obtained slabs of a strength of 7 kg. or 8 kg. (even, 14 kg.) per sq. cm., and the slabs from extracted cork were only slightly inferior in strength to the others. Slabs of a certain tensile strength—the determinations were made on a cement-testing machine—could be obtained even at the temperature of 50 deg. C., combined with compression; heating before compression proved useless. As the pressure increased, the differences between the treated and the untreated cork meal vanished more and more. The compressed cork plates adhered to the walls of the mould (iron, copper, platinum, rough or smooth), but not when tissue paper was interposed, and this paper did not appear to be impregnated with oily resin subsequently. The steaming tests are also against the natural-resin theory. Ordinary cork matting, prepared with binders, is not destroyed by the action of steam. In the absence of binders, steam does cause disintegration of the slabs, extracted or not, unless the compression has been combined with heating to 160 deg. or higher temperatures, and hot alcohol, which is a solvent of the resin, is not more injurious than water in this respect. Ost's idea is that the strength of the cork slabs depends upon the interlocking and felting of the cork cells. Strongly-compressed for a long time, cork (from a champagne bottle, *e.g.*) turns hard and inelastic; the elasticity can be restored by steaming the cork, when it swells again. High temperature, combined with compression, however, destroys this elasticity, the cork grains turn indifferent, and subsequent steaming does not interfere with their felting. The ordinary addition of resinous binding agents to the cork waste surrounds the particles with a skin which is more or less impermeable to water; hence the greater resistance to the disintegrating action of steam.

NOTICES OF MEETINGS.

THE INSTITUTION OF LOCOMOTIVE ENGINEERS (LONDON).—Tuesday, September 24, at 7.30 p.m., at the Philosophical Hall, Park Row, Leeds, a paper will be read by Mr. H. Kelway-Bamber, on "Coal and Mineral Traffic on the Railways of the United Kingdom."

THE INSTITUTION OF RAILWAY SIGNAL ENGINEERS (INCORPORATED).—Wednesday, September 25, at 2.30 p.m., at the Midland Grand Hotel, St. Pancras, for the purpose of continuing the discussion on Mr. H. M. Proud's paper, "A Graphical Method of Solving Direct-Current Track Circuit Problems."

THE INSTITUTION OF LOCOMOTIVE ENGINEERS, LONDON (INCORPORATED).—Thursday, September 26, 1918, at 7 p.m., at Caxton Hall, Westminster. Paper by Mr. J. Carlier, on "The Heating of Trains and the Problem of Coal Saving."

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, September 27, at 7.30 p.m., at the Office, 39, Victoria-street, Westminster, S.W. 1. Paper on "The Most Important Piece of Material in the World," by Mr. Percival Marshall.

THE INSTITUTION OF MECHANICAL ENGINEERS: THE THOMAS HAWKSLEY LECTURE.—The annual Thomas Hawksley Lecture will be given (in the meeting hall of the Institution of Civil Engineers) by Dr. W. Cawthorne Unwin, F.R.S., on Friday, October 4, at 6 p.m.; subject, "The Experimental Study of the Mechanical Properties of Materials."

THE FATIGUE OF METALS.—The National Research Council, acting as the Department of Science and Research of the Council of National Defence, has appointed a committee to investigate the fatigue phenomena of metals. Professor H. F. Moore, of the Engineering Experiment Station of the University of Illinois, is chairman. The committee is charged with the responsibility of developing a knowledge of the strength and durability of metals subjected to repeated stresses, such as ship structures, crankshafts of aircraft engines, and heavy ordnance. It is expected that much of the experimentation required will be done in the laboratories of the University of Illinois at Urbana under the personal direction of Professor Moore.

FABRICATED SHIP CONSTRUCTION AT HOG ISLAND.—According to *Contracting* the first of the 180 ships contracted for at the Hog Island yard was launched on August 5, or in but eleven months after work had been commenced in laying out the yard. The ship measures 400 ft. in length by 54 ft. in width and contains 2,500 tons of steel, which was rolled in 27 different mills and fabricated in 70 shops. The ship is fitted with engines developing 2,500 h.p. and will have a speed of 11½ knots. The cost is said to have been 1,050,000 dols. Forty other ships were in progress at the date of the launch.

SYNTHETIC GASOLINE BY ELECTROCHEMICAL MEANS.—Under this ill-chosen title, Mr. L. Bond Cherry described last October some experiments on what might be characterised as a High-Tension Discharge Cracking Process; the experiments have been conducted on a fairly big scale. He passes mixtures of petroleum vapours and hydrogen (or natural gas, etc.) through electrically-heated iron tubes while high-tension, high-frequency currents are sent through the axial wire electrode of each tube. The process is thus a combination of the ordinary cracking process and the Cottrell process; but the inventor claims that the high-frequency discharge does away with the need of high pressures and prevents the deposition of carbon at high temperatures and the formation of olefines. A further novelty is that he introduces the gas (natural gas, steam), the hydrogen of which is to combine with the hydrocarbons through a perforated pipe under pressure into the oil in the still, thus facilitating the evaporation of the oil. He first experimented with tubes (iron pipes) 3 ft. high; the height was afterwards raised to 10 ft. and even to 34 ft., and finally a conversion of 84 per cent. of the heavy oil into a gasoline was obtained; Cherry did not give any analytical data, but merely gravity figures, however. The actual equipment (locality not mentioned) is for heating 60,000 gallons of oil per day by currents of more than 35,000 vibrations per second at tensions ranging from 25,000 volts up to 250,000 volts. The construction of the plant for work at high temperatures (up to 538 deg. C.) and pressures (5.5 atmospheres) naturally caused serious difficulties, and working at atmospheric pressure was for this reason adopted. The paper says more about parts of the apparatus than about the actual working, and the whole would be more impressive if statements like the following had not been made: "After studying the electromagnetic theory of matter it was conceived that, if the only difference that existed between carbon and hydrogen and between the lower and high members of the paraffin series was the number and organisation of infinitesimal units of electro-radiant energy which we are pleased to term electrons, and if we mechanically mixed vapours . . . and impressed upon the mixture electro-radiant energy of the proper periodicity . . ." However, it seems evident also from the description of the paper, that the problem has been attacked in a practical way, and it might certainly be an advantage if some such treatment could be combined, as is suggested, with the crude-oil distillation in the refineries. Electric heating of the tube is considered necessary because a careful temperature control is required. It is certainly remarked that the high-tension discharge should prevent the deposition of coal on the hot iron walls.

REINFORCED CONCRETE 3,500-TON DEADWEIGHT U.S. SHIP.

(*For Description, see Page* 326.)

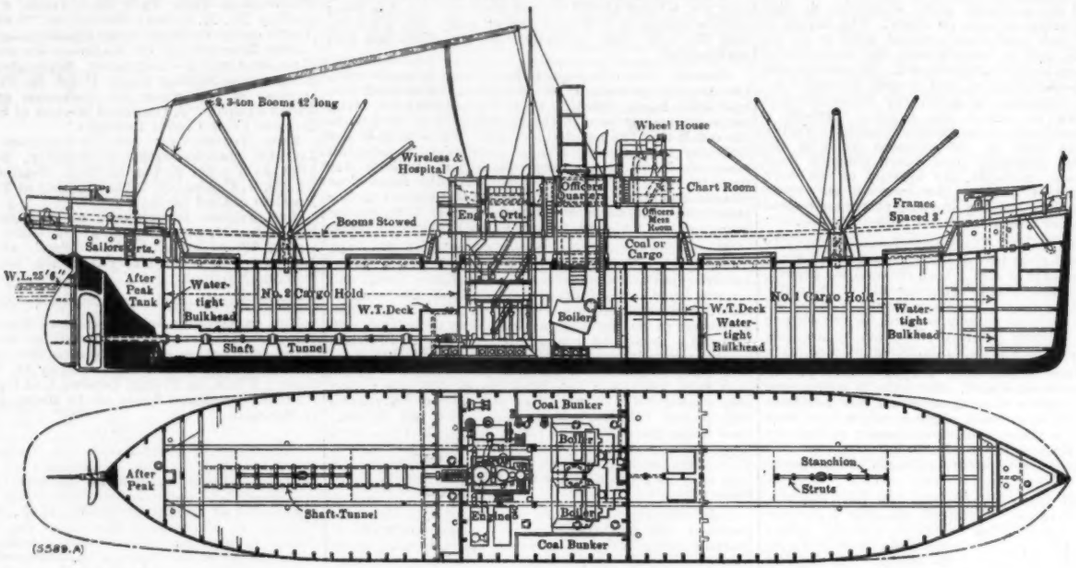


Fig. 1.—Inboard Profile and Hold Plan of 3,500-Ton Concrete Ship

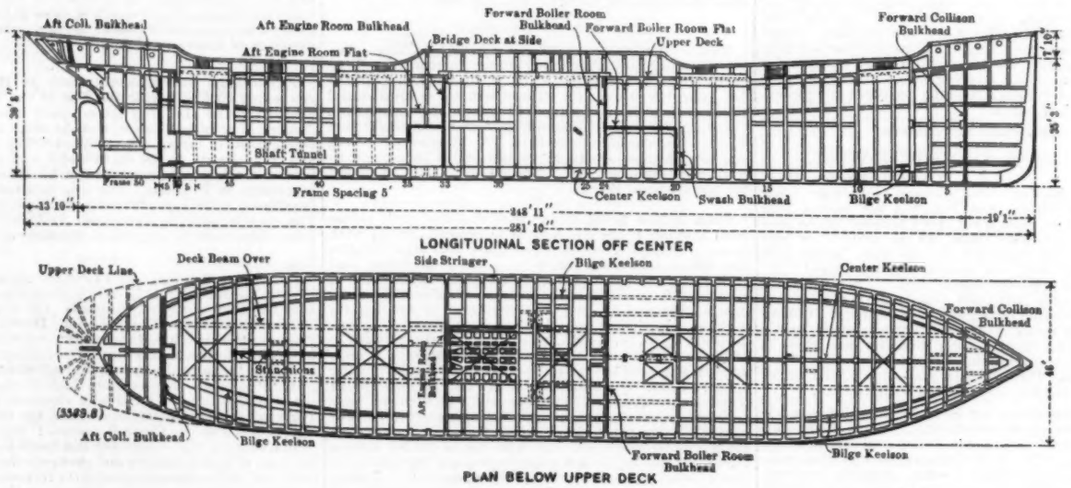
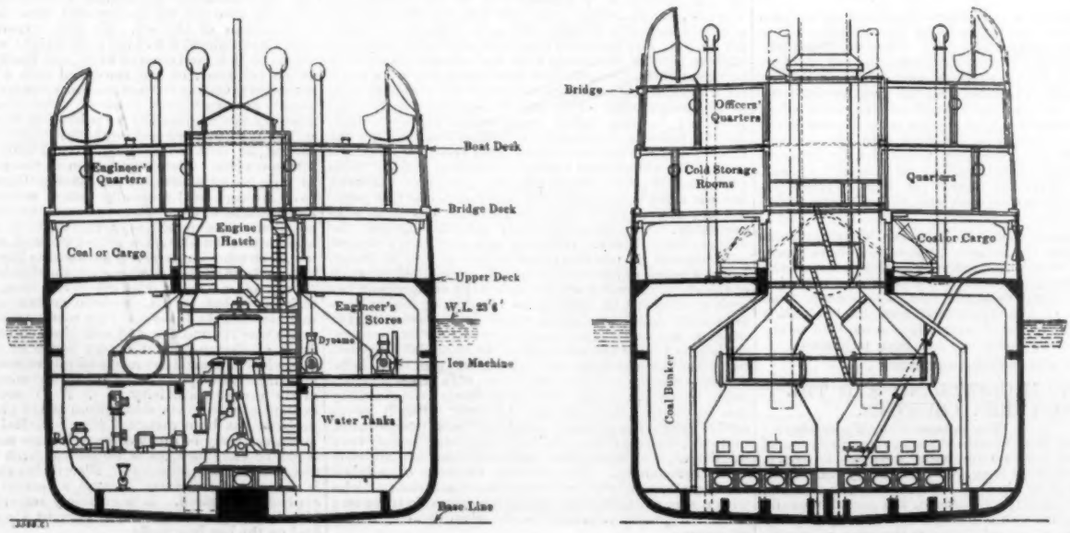


Fig. 2.—Frame Plan



Section Through Engine Room (Looking Forward) Section Through Boiler Room (Looking Aft)

Fig. 3.—Sections Through Machinery Space

TEMPLETS, JIGS AND FIXTURES.

MESSRS. GLENFIELD AND KENNEDY, LIMITED, KILMARNOCK.

(For Description see Page 308.)

Fig. 368

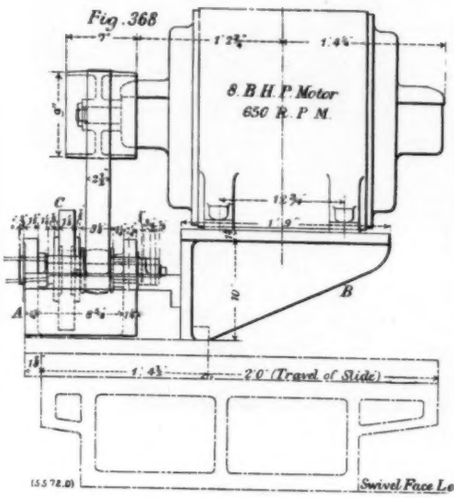


Fig. 370.

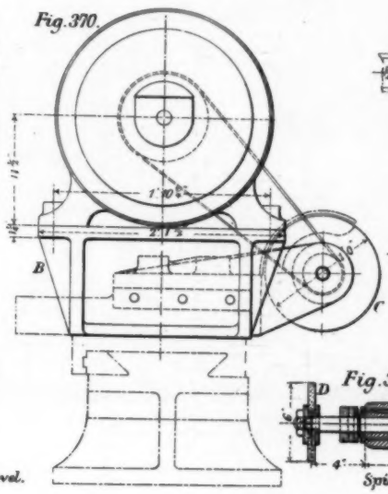


Fig. 369.

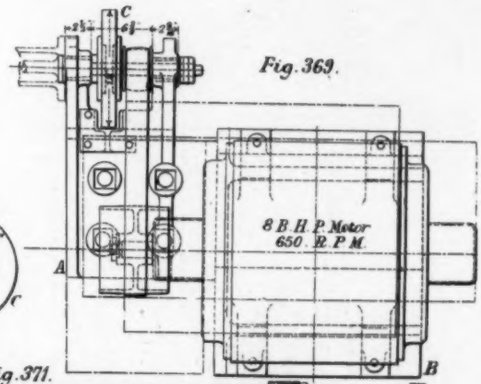


Fig. 371.

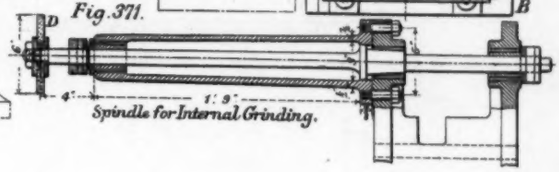


Fig. 372.

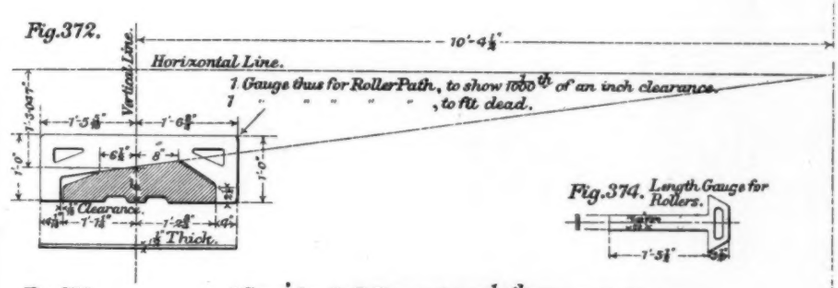

Horizontal Line.
1 Gauge thus for Roller Path., to show 1/1000 of an inch clearance.
1 " " " " " , to fit dead.
Vertical Line.
Clearance.
Thick.

Fig. 374. Length Gauge for Rollers.

Fig. 375.

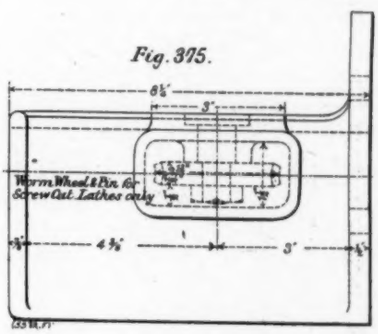


Fig. 373.

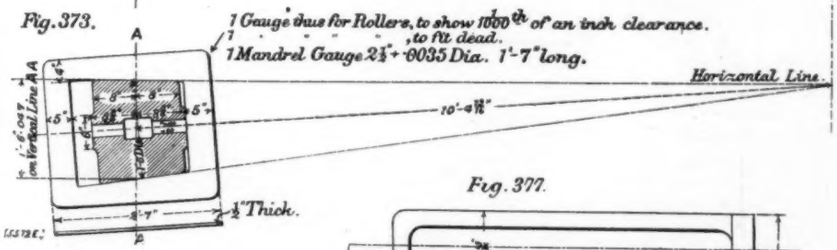

1 Gauge thus for Rollers, to show 1/1000 of an inch clearance.
1 " " " , to fit dead.
1 Mandrel Gauge 2½" +.0035 Dia. 1'-7" long.
Horizontal Line.
Thick.

Fig. 376

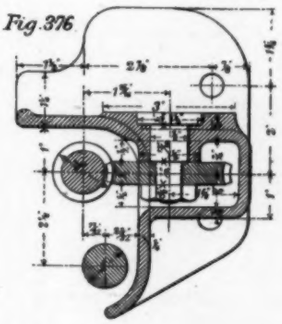


Fig. 377.

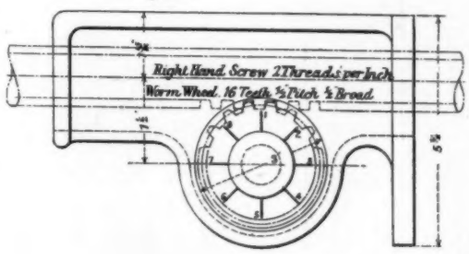


Fig. 381.

Fig. 378.

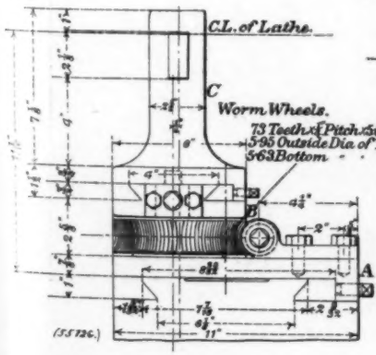


Fig. 380.

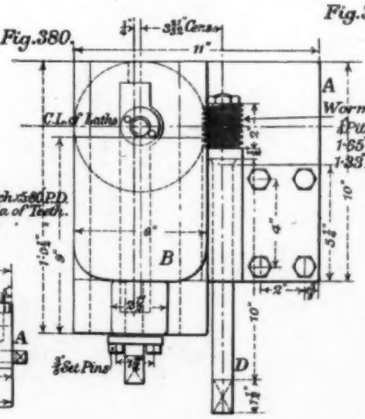
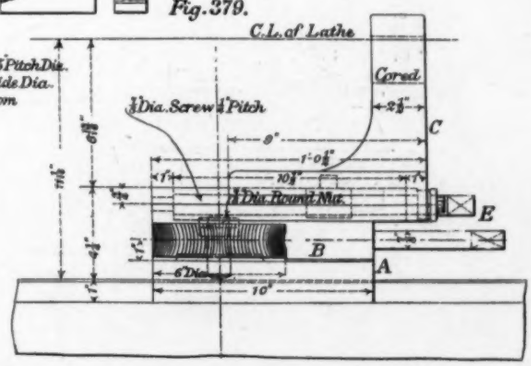


Fig. 379.

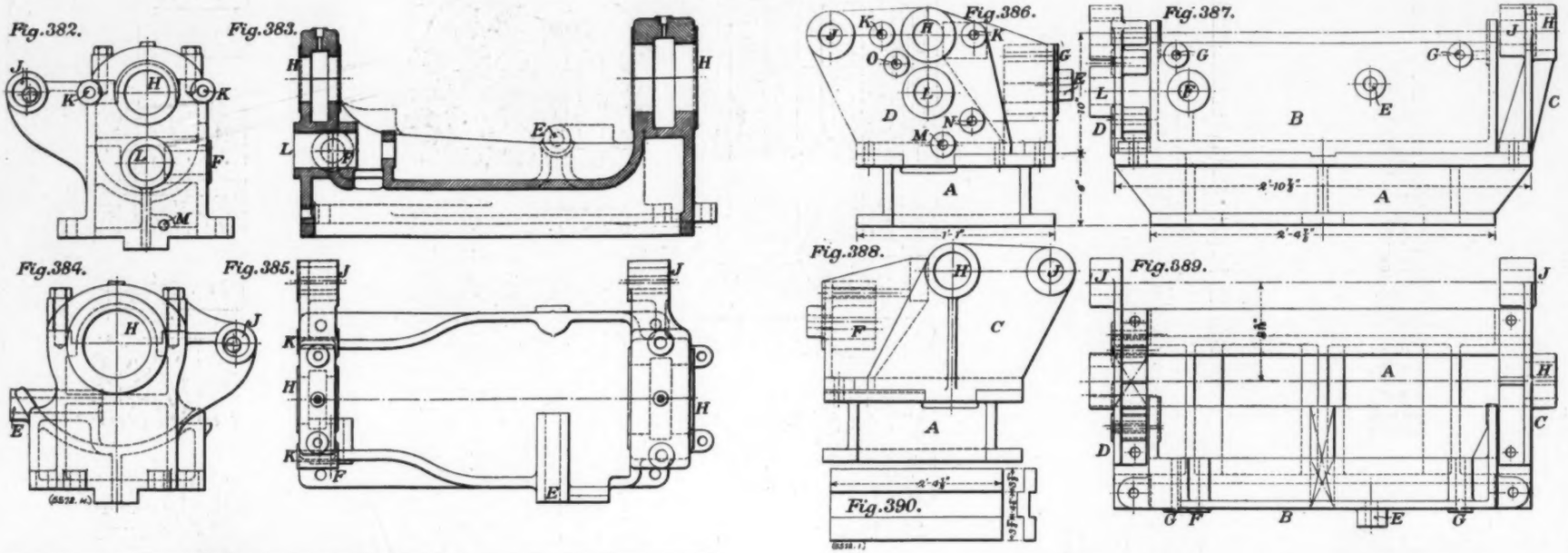


(To face page 310.)

TEMPLETS, JIGS AND FIXTURES.

MESSRS. GLENFIELD AND KENNEDY, LIMITED, KILMARNOCK.

(*For Description see Page* 308.)



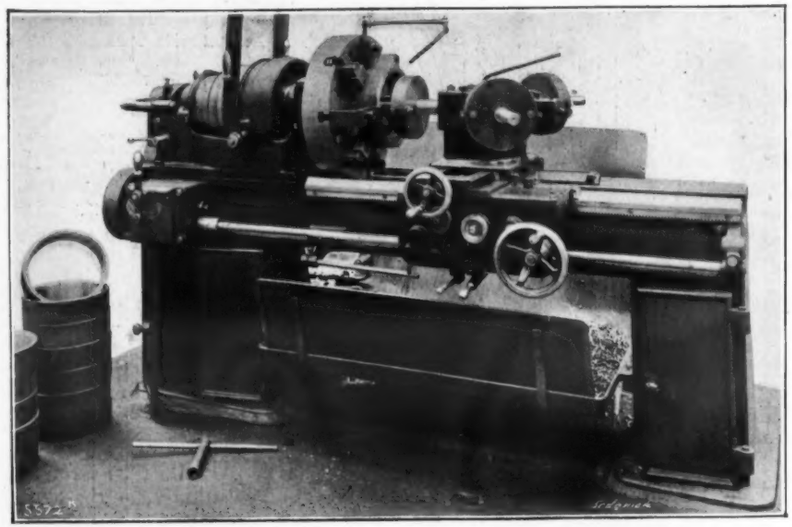


FIG. 391.

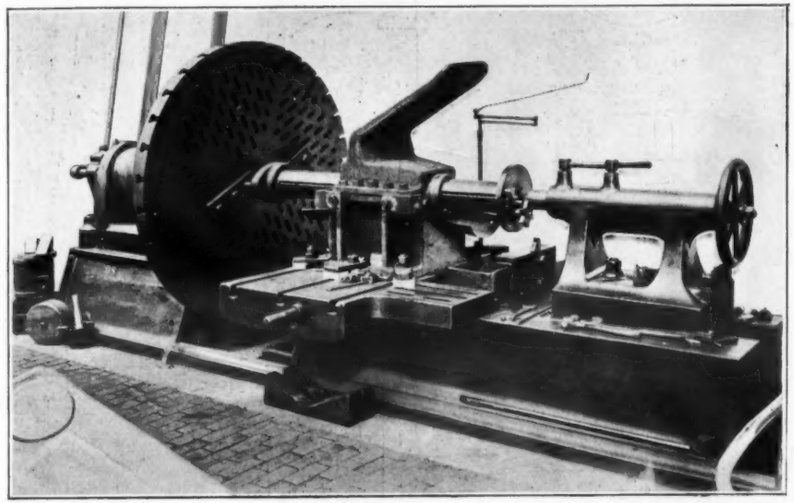
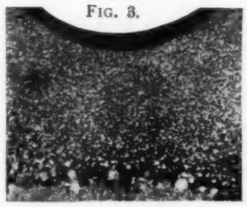


FIG. 392.

GRAIN GROWTH IN METALS.

(*For Description see Page* 328.)

FIG. 3.

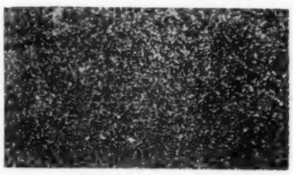


Steel ·05% C. heated 7 hr. at 650°C. after Brinell impression. × 6. *Sauveur.*

FIG. 4.

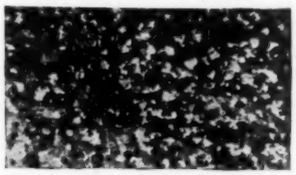
Steel ·05% C. bent cold and heated 7 hr. at 650° C. × 6. *Sauveur.*

FIG. 5.



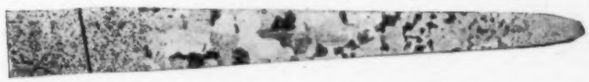
Steel ·05% C. stressed cold to 38,000 lb. per sq. in. and heated 7 hr. at 650° C. × 6. *Sauveur.*

FIG. 6.



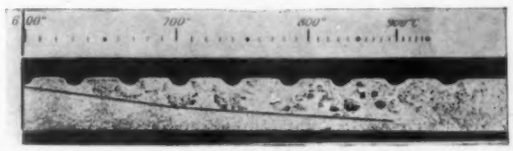
Steel ·05% C. stressed cold to 40,000 lb. per sq. in. and heated 7 hr. at 650° C. × 6. *Sauveur.*

FIG. 7.



Strain gradient produced by stressing tapered bar. Then heated to 870° C. × 4·75. *Chappell.*

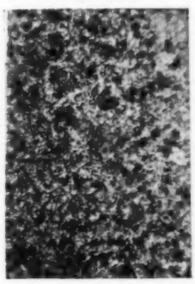
FIG. 8.



Effect of strain and temperature gradients on grain size of low-carbon steel. × 4. *Chappell.*

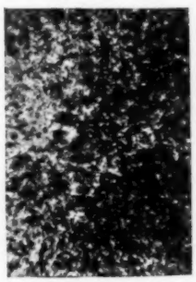
GERMINATIVE GRAIN GROWTH IN LOW-CARBON STEEL.
Reduced by one-third.

FIG. 9.



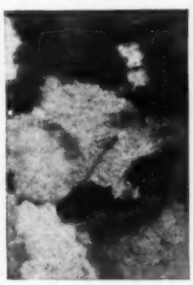
1% ThO_2

FIG. 10.



2% ThO_2

FIG. 11.

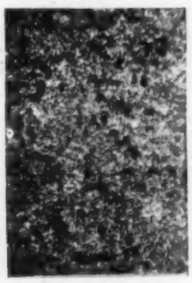


3% ThO_2

FIG. 12.

4% ThO_2

FIG. 13.



5% ThO_2

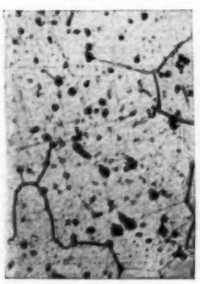


FIG. 14.

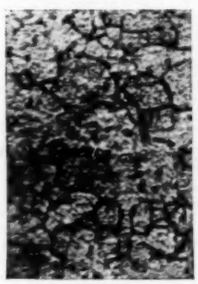


FIG. 15.

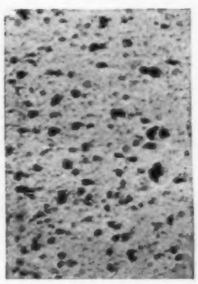


FIG. 16.

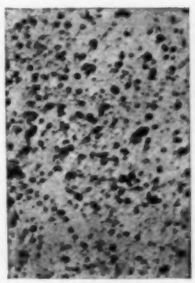


FIG. 17.

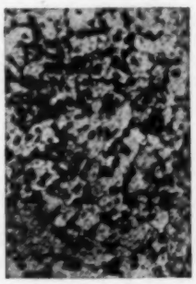
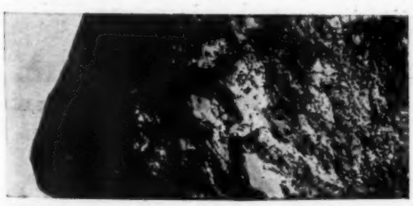


FIG. 18.

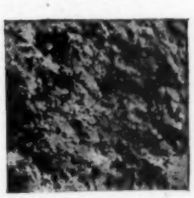
Tungsten containing various percentages of ThO_2, pressed from powder and then sintered below melting point by heating for 12 min. at about 3,200° C. by electric current in hydrogen atmosphere. Upper row × 20, lower row × 500.
Reduced by one-ninth.

FIG. 19.



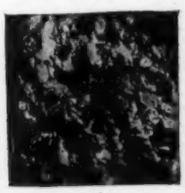
Longitudinal fracture of end of ingot near cold electrode clip. Central portion heated to fusion but not shown in photograph.

FIG. 20.



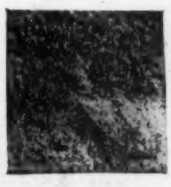
Heated to 2,600° C. for 20 min. Transverse fracture.

FIG. 21.



Heated to 2,600° C. for 30 min. Transverse fracture.

FIG. 22.



Heated quickly to 3,200° C. and exposed 30 min. Transverse fracture.

FIG. 23.

Same as 22, polished and etched.

Tungsten containing 0·75% ThO_2, pressed from powder and heated below melting point by electric current in hydrogen atmosphere. All × 5.

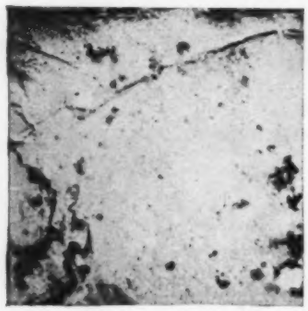
(*To face page* 328.)

(*To face page* 311.)

GRAIN GROWTH IN METALS.

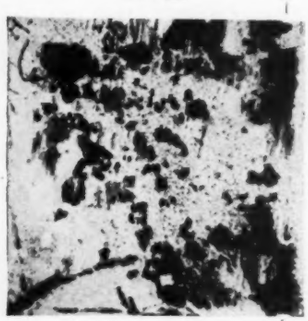
(*For Description see Page* 328.)

FIG. 24.



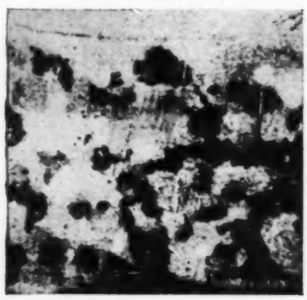
Heated to 2,600° C. for 20 min. Transverse section.

FIG. 25.



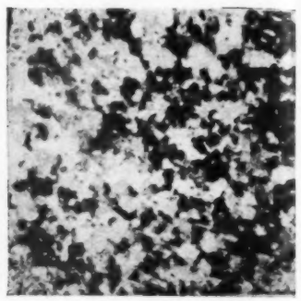
Heated to 2,600° C. for 30 min. Transverse section.

FIG. 26.



Same as 25. Longitudinal section at *a–a*.

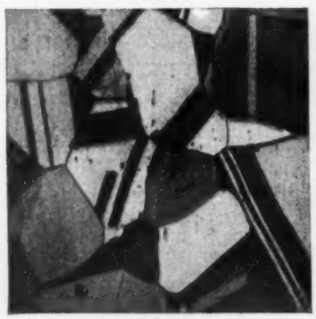
FIG. 27.



Heated to 2,600° C. for 20 min. and then to 3,200° C. for 10 min. Transverse section.

Tungsten containing 0·75 per cent. ThO_2, pressed from powder and heated below melting point by electric current in hydrogen atmosphere. All × 10. Reduced by one-fifth.

FIG. 28.

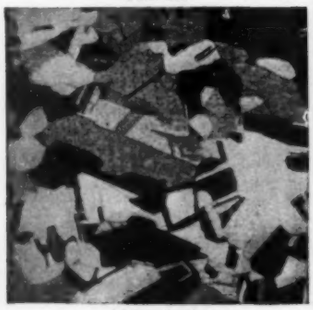


4% reduction.

FIG. 29.

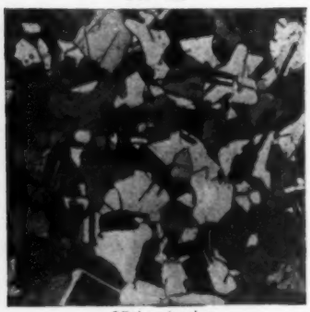
8% reduction.

FIG. 30.



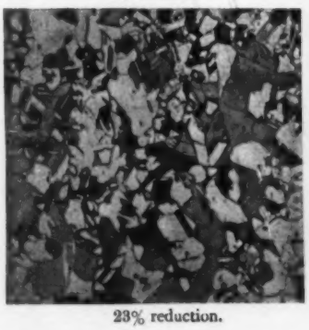
12% reduction.

FIG. 31.



15% reduction.

FIG. 32.



23% reduction.

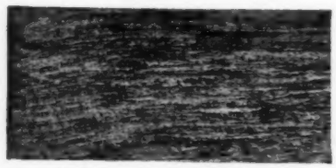
FIG. 33.

50% reduction.

Mathewson & Phillips

Alpha Brass reduced various degrees by cold rolling and then annealed for 30 min. at 550° C. × 85.

FIG. 34.

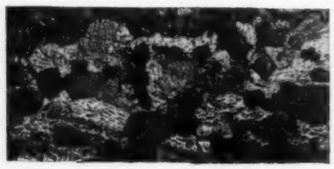


Tungsten severely worked below equiaxing temperature. × 200.

FIG. 35.

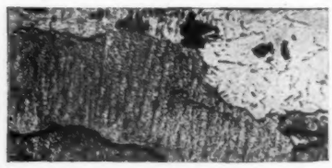
Same near electrode clamp after heating 9¾ hr. to 3,000° C. × 200.

FIG. 36.



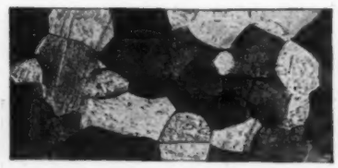
·007 in. wire heated quickly to 2,900° C. × 100.

FIG. 37.



·007 in. wire heated slowly through germinative temperature range. × 500.

FIG. 38.



·080 in. rod heated quickly to 3,000° C. × 100.

FIG. 39.

·080 in. rod heated slowly to 3,000° C. × 100.

Effect of temperature and temperature gradient on grain size of tungsten severely worked below its equiaxing temperature. Temperature gradient obtained by electric current heating.

Reduced by one-fifth.

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TELEPHONE NUMBERS—8803 and 8808 GERRARD.

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With Two One-Page Plates of TEMPLETS, JIGS AND FIXTURES, and Two One-Page Plates of the GRAIN GROWTH OF METALS.

NOTICE.

Owing to the recent Government restrictions, and to the enormous increase in the price of paper occasioned thereby, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal further from 9d. to 9d. per copy. This increase dates from and includes the issue of Friday, March 1, 1918. The change will not apply to unexpired subscriptions. The revised rates for new subscriptions are given in the adjoining column.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper and the consequent shortage of supplies, Newsagents will not have copies for chance customers; therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 317.

ENGINEERING.

FRIDAY, SEPTEMBER 20, 1918.

INTERNAL-COMBUSTION ENGINES FOR SUBMARINES AND AIRCRAFT.

THE two outstanding types of internal-combustion engines, where the total weight of the complete prime mover (measured preferably in the condition for running at full power) is of primary importance, may be said to be the petrol engine for aircraft and the Diesel engine for submarine propulsion. The importance in design to be allocated to various other essential factors, apart from the consideration of weight, will vary in accordance with the type of aircraft to be engined and also, in lesser measure, with the requirements of the class of submarine in question. Briefly, these factors may be stated as: Capacity for running at approximately full power for lengthy periods under working conditions, without requiring undue attention, adjustment or overhaul; fuel and lubricating oil consumption; accessibility for ease and speed of adjustment and overhaul; and facility of manufacture, availability of raw materials, cost, &c.

A few examples readily show the difference in the relative values that have to be assigned to these factors strictly according to the merits of the particular case. In regard to the capacity to develop full power under working conditions, consideration in aeroplane and airship work must be given to the reduced density of the atmosphere at the normal altitude of flight. The period of running at full power without attention, will be determined by the duties assigned to the particular type of craft, suitable factors of safety being allowed for contingencies. With aeroplanes, when in flight, running adjustments to the engines cannot be made, whereas in the case of airship machinery the conditions are more favourable for such alterations. Indeed, the published logs of the long trips of Zeppelins record that minor repairs have been carried out when underway. In the case of submarines, repairs and even minor overhauls are possible at sea. The combined fuel and lubricating oil consumption has, in all cases, a value increasing in importance with the radius of action demanded, generally in this order: aeroplanes, airships and submarines. Accessibility, conducive to ease and speed of adjustment and overhaul, is always of importance even for aeroplane work, where such qualities make for the maximum utility from a given number of machines and reduce to a minimum the personnel attached to an air squadron and responsible for upkeep. It has however, still greater value in the case of submarine work. Ease of manufacture, too, is a quality that will always enhance the value of any design. Quantity and quality are requirements of a somewhat conflicting nature, and whilst the design, which embraces compromises at the highest mean value between these extremes, will be very acceptable, there will always be a field for the absolute best. The question of weight per unit of power even with these qualifications is a most important factor in all the applications named, and in the development of aero engines the reduction in the weight, increase in power, and improvement in reliability, consumption and accessibility, form most interesting features in modern engineering.

With internal-combustion engines, the larger the power per cylinder the higher the weight per unit of power developed, due primarily to heat stresses requiring a reduction in effective mean pressure developed within the working cylinder, and to large increases in the thickness of the metal to conduct away a sufficient percentage of the surplus heat of combustion. With aero engines, the weight varies from 6 lb. to 3 lb. or even less per brake horse-power developed, according to the type of engine, whereas on an exactly similar basis of measurement, the weight of submarine Diesel engines is from 60 lb. to 40 lb. per brake horse-power. This it will be seen is a large difference, and an examination of some of the causes of this difference may suggest improvements in design in respect of weight in the case of the submarine engine. The following factors are enumerated as tending in the direction of accounting for this difference: The large power per cylinder of submarine engines, which means, as already explained, an increase of weight per unit of power. The power of aero engines is from 20 brake horse-power to 30 brake horse-power and of submarine engines from 100 brake horse-power to 250 brake horse-power per cylinder, explaining largely the difference in m.e.p. on a brake horse-power basis, viz., 140 lb. per square inch with aero engines and 100 lb. or less with submarine engines, both using fuel of about the same calorific value. Whilst the compression pressure determines the maximum pressure of combustion developed in a cylinder—and with Diesel engines the compression pressure may be as high as from three to five times that of a high-compression aero engine—yet the normal maximum pressure in a high-speed Diesel engine cylinder is not more than some 50 per cent. greater than in a high-speed petrol engine, viz., 500 lb. to 600 lb. per square inch as against 300 lb. to 400 lb. per square inch. The possibility of the development of excessive pressure in a Diesel engine cylinder is not fully allowed for by the fitting of relief valves.

The relatively small power per unit, the consequent light weights to be handled during overhaul, and the fact that the aeroplane is built round the engine, permit of an arrangement of working cylinders with aero engines such as the V and Ψ arrangements which make for reduced weight, but which are not so permissible where large weights are concerned, nor for marine engines. With the latter the period of running at full power is longer than with aircraft engines, and although adjustment can be made underway, the size of the engine almost requires the means of adjustment apart from the conditions of duration of period of running. Such means of adjustment, of course, involve extra weight. This period of running at full power makes necessary the accessibility of the main parts for adjustment and even minor overhaul when at sea, with the utilisation of the limited appliances provided to that end. Moreover, marine engines are expected to remain in satisfactory working order and capable of developing full power without requiring any considerable overhaul except after lengthy periods of service. Marine requirements and the size of the engines in question involve starting devices and mechanism with their attendant weight. The question of the consumption of fuel and lubricating oil has, as already explained, a high value, especially where the duration of the period of running at full power is lengthy.

With both air and submarine craft the overall efficiency is the only true basis of comparison, and the influence of the speed of rotation of the propeller on the design of power plant must be considered. With certain air craft, gearing is introduced between the engine and the propeller, thereby equating conditions of maximum efficiency of propeller with maximum efficiency per unit weight of engine. The other and general solution is a compromise between the conditions of maximum efficiency of propeller and engine design, due regard being paid to the question of weight. With sub-

marine design compromise has been regarded in the past as entirely satisfactory, and with increasing power of propelling machinery and higher surface speed of the craft, a solution of the various factors of the problem influencing maximum overall and unit efficiency is still more easily obtained without gearing. One of the principle factors in such considerations is that of piston speed which in the case of aero engine work has steadily been increased. With submarine engine work there seems thus no reason why the piston speed should not attain a figure much more in keeping with aero engine practice without adversely influencing overall efficiency, provided full use is made of the same materials; this point will be returned to later.

Whilst the foregoing do not represent all the points of difference in regard to the extra weight of the Diesel engine per unit of power, yet, they may be said to be the principle ones, and it is felt that they do not satisfactorily explain the large difference in weight, *i.e.*, 10 to 1. Other solutions towards explaining this difference may well be reviewed, and aero engine practice considered with reference to the future possibilities of submarine Diesel engine design. It should be pointed out that until such time as aero engine practice departed radically from motor car petrol engine design, the reduction in weight effected was limited. Similarly with submarine Diesel engine work the influence of the slow-running four-cycle land engine, where weight is of little consequence—a type which represents the greater percentage of Diesel engines turned out—is still strongly felt, and, if the future design of submarine Diesel engines could be regarded afresh from first principles, there is a probability that considerable reduction in weight could be achieved. In this connection the following points suggest themselves. A very large amount of weight is centred in the piston, gudgeon pin, connecting rod and crankshafts of Diesel engines. The pistons are of cast-iron and generally air cooled so that the thickness of metal is very considerable in order to allow for heat transference from the pistons to water jackets, whereas, there is no reason why metals more suitable for heat conduction should not be utilised. The gudgeon pin, connecting rod and crankshaft, if of suitable dimensions and of high tensile heat-treated steel, the reliability of which is amply proved, could be greatly reduced in weight and still allow for a factor of safety to meet the necessities of the case. These alterations would permit of much higher piston speeds than the arbitrary limit of 1,000 ft. per minute to which designers have almost rigidly worked in the past.

In regard to the framing of the engine, little reduction can be expected, except by the full utilisation of thin steel castings for the cross girders of the bedplate and of high tensile steel forgings to take the main tension stresses resulting from the piston loads. The weight of the valve gear is a relatively small percentage of the total and is generally fairly well studied. As already stated, the m.e.p. of Diesel engines is considerably lower than with aero engines. By studying the question of heat conduction and utilising materials of high heat conductivity, by improvements in the scavenging of the exhaust charge and the introduction of the air into the working cylinder, together with the all-important question of atomisation and ignition of the charge, it may be confidently hoped that higher m.e.p.'s than in present practice could be sustained, possibly with substantially lower compressions, without incurring detrimental results so far as reliability is concerned. This would lead to future designs, where the weight per unit of power developed would not be much greater than half that at present required, reducing the ratio of weights in submarine and aero engines from the 10 to 1 already mentioned to some 6 to 1 or even 5 to 1.

ACETYLENE WELDING.

DURING recent years fusion welding, which includes of course acetylene welding, has spread in all departments of engineering until now we hear of boilers and stern frames being successfully repaired; and it is seriously discussed whether many kinds of shipwork now riveted might not be more economically joined by welding. As announced in a recent issue a barge has just been launched on the South Coast built entirely without rivets. The shell up to and including the bottom seam of the bilge plate is continuously welded inside and out by the electric arc process. The frames, floors, decks and brackets are all "tack" welded, that is, short sections of 3 inches are welded, with intermediate spaces of some 6 inches unwelded. Butt welding has been adopted for the deck plates, and lap welding for the shell plates. In America the Emergency Fleet Corporation has already authorised the building, at the Newark Yard of the Submarine Boat Corporation, of an experimental 50-ft. section of a 9,000-ton ship completely electric welded. In this all methods of welding will be given a fair trial. In the meantime welding is to be introduced in the construction of many vessels already on the stocks as far as experience warrants. The Technical Committee of Lloyd's Register have just recommended to the General Committee certain recommendations put forward by the Chief Ship Surveyor as to the conditions as to which welding might be adopted instead of riveting in the construction of vessels.

The advent of mild steel tended to displace the art of welding, partly because of the great difficulty as compared with iron, and partly because of the tractable nature of steel which lends itself more readily to pressing and stamping. The introduction of fusion welding, however, wrought a great change, and now in scores of shops it is practised on a large scale. In munition factories dealing with aeroplanes dozens of girls are to be seen welding fittings for connecting the timber struts and the wires ties, and the number of welds made per day are to be counted in thousands. Whether they are all sound joints is a matter on which one would like better assurance than is possible, since it is only by tests to destruction that the integrity of a weld can be demonstrated, and such tests are impossible except on selected examples. It is very easy to make nice looking welds, but appearance is no guarantee of solidity, and under a smooth surface it is by no means infrequent to find laminations separated by dark streaks in which there is no real union.

One has always to bear in mind that a fusion weld which is not subject to thorough work, either by hammering or rolling, can never be as strong as the metal it unites. This was demonstrated years ago in the University of Illinois Engineering Experiment Station. The results of the test of hundreds of welds were published,* and although occasionally figures of efficiency of 95 per cent. were reached, the general average was only about 72 per cent., and often the figure fell to 48 per cent. In these tests care was taken to grind the welds to the same thickness as the plate; better results could, of course, have been attained if the welds had been built up to give an increased section to the weak metal. The tests were made by assistants in the laboratory, who, although fully skilled in many ways, were unversed in welding. Their work improved as they gained experience, but they never surpassed the results noted above.

In a later series of tests published in 1917† the joints were welded by skilled workmen in a plant especially equipped for oxyacetylene welding, and the plates, instead of being all sheet metal, varied in thickness from No. 10 gauge to 1 in. Very elaborate tests were made of the joints, which were purposely left thicker than the plate. In the thin metal this raised the strength of the joint above that of the material itself, but not so in the thicker plates, as of course, the extra thickness was a small percentage of the thickness of the plate. The annexed table sets forth the percentage efficiency of the material in the joint based on its ultimate strength, the thickness being that of the plate.

Under repeated stress the joints gave somewhat better results, showing that the welds are not more susceptible to this kind of test than to direct pull. Under impact test, however, the joints

Thickness of Plate.	No. 10 Gauge.	¼-In.	½-In.	1-In.
Material of plate annealed from 800 deg. C.	91	96	92	89
Joint welded, no subsequent treatment.	—	73	77	71
Joint welded, annealed from 800 deg. C.	—	—	75	65
Joint welded, quenched from 800 deg. C.	—	—	78	76
Joint welded, hammered while hot.	—	—	77	80
Joint welded, hammered while hot, annealed from 800 deg. C.	—	—	76	74

gave only poor results, as shown by the following table:—

Thickness of Plate.	¼-In.	½-In.	1-In.
Material in plate annealed from 800 deg. C.	97	93	89
Joint welded, no subsequent treatment ..	64	37	53
Joint welded, annealed from 800 deg. C...	66	37	35
Joint welded, quenched, annealed from 800 deg. C.	88	44	32
Joint welded, hammered while hot ..	89	48	53
Joint welded, hammered while hot, annealed from 800 deg. C.	72	41	53

Impact tests are notoriously erratic, but it is clear from the above that fusion welded joints in thick plates are not well adapted to withstand this kind of stress. Even when the joint is hammered while hot, which it is not generally possible to do very effectively, the efficiency is far below that of the annealed plate, and little more than half that of the plate as received.

Fusion welding, whether electric or acetylene, depends for its efficiency upon the skill of the operator, and that depends in nineteen cases out of twenty on the way in which he (or she) has been taught. There is a great deal to be learned. The adjustment of the gas mixture, the correct position of the flame in relation to the work, and other details must be properly understood, and the class of labour which has flocked into munition works has to be taught to do each job from beginning to end, that is, it cannot be shifted from one job to another unless it is at the same time properly instructed.

During the last two years quite a number of papers on fusion welding have been read before technical societies, and in every one of them stress has been laid on the necessity of systematic and painstaking instruction being given to the operatives. A capable mechanic will, of course, soon grasp the principles of the process and will adapt his methods to the conditions of each job. But skilled men are relatively very scarce now, and they are only employed on the really important jobs. On the face of it the blowpipe appears to be a very simple appliance, and it is only the expert who realises in how many directions errors of operation can creep in. Some of these are quite beyond the control of the operator and must be watched by the management. Captain D. Richardson, R.F.C., in a paper read before the British Acetylene Association last March, pointed out that failures of welded joints may often be traced back to the apparatus or the gases. Overloading of the apparatus often leads to bad results. A generator which is driven beyond its proper capacity gives a gas saturated with tarry products, water vapours, lime dust and chemical impurities. Even if the generator is working well, the subsequent purification of the gas may be insufficient. It has been stated that not one acetylene man in ten keeps his purifier in a really efficient condition. Unless the purifier is working well it is impossible to guarantee that tar, water vapour, and lime dust shall not reach the weld and give rise to stratification. Defective welds are also caused, according to Captain Richardson, by the piping being too small and leading to the aspiration of air through the hydraulic safety valve; by the regulators, which easily get out of order and do not deliver the gases in unvarying proportions and at the correct pressure; and by flexible tubes which are too long and too flexible.

It is thus seen that the apparatus supplied to the operator, and over which he has little or no

* University of Illinois Bulletin, No. 45. The Strength of Oxyacetylene Welds in Steel. By Herbert L. Whittemore. September, 1910.

† University of Illinois Bulletin No. 98. Tests of Oxyacetylene Welded Joints in Steel Plates. By Herbert F. Moore, Research Professor of Engineering Materials. London: Chapman and Hall.

control, may render it very difficult for him to turn out good joints. He may also be handicapped by the design and preparation of the work. Lap joints are difficult to make, and if the bevelling and cleaning of the pieces are not properly carried out, burning, bad penetration and oxide inclusions are the natural result. The necessity of providing for expansion is frequently overlooked, and the methods for relieving the stresses in the surrounding metal need to be systematically taught. In fact acetylene welding is essentially a skilled operation. It may, however, be carried out by unskilled labour if this be confined to repetition work and be carefully instructed beforehand. In many cases not nearly enough attention is devoted to this subject, and operators are set to work after a very cursory preparation. Further, it is to be feared that the teachers are often badly equipped for their task. Many demonstrators from colleges have adopted this calling, and although they are generally able to teach what they know, they are usually very deficient in workshop practice. The American experiments we quoted showed that laboratory assistants needed considerable practice before they could make good welds, even when they had the advantage of seeing them all tested to destruction as the trials went on. There have certainly been instances in which the instructors here have been blind guides of the blind, and have done little for their pupils beyond making them content with unsatisfactory methods. It would be a great pity if such a valuable process as acetylene welding certainly is, were to fall into discredit by reason of its being carried out by inefficient operators. This is a matter which has always been realised by the British Acetylene and Welding Association who for years have been providing instructors to enable engineers to take up the process with every prospect of success. The war, however, has widened the demand so greatly and suddenly that many works have been obliged to adopt the system without realising all its difficulties and the need of acquiring the experience of their predecessors.

THE IRON AND STEEL INSTITUTE.

As announced on page 294, *ante*, the opening meeting of the autumn session of the Iron and Steel Institute was held on Thursday morning, 12th inst., in the hall of the Institution of Civil Engineers, the president, Mr. Eugene Schneider, occupying the chair.

Influence of Hot-Deformation on the Qualities of Steel.

The first paper taken was one on the "Influence of Hot-Deformation on the Qualities of Steel," by Mr. Georges Charpy (Paris). It was read in abstract by the secretary; Mr. Cornu-Thénard, a collaborator of Mr. Charpy, assisted at the meeting. We reproduce this paper in full on page 310 of the present issue, and need not therefore refer to it specially here.

The discussion was opened by Dr. Stead, who said it was thought hitherto that the more work was put on steel the better it became, whilst the author, in his paper, implied that such was not the case; that as far as securing tenacity in the cross-direction is concerned the more work was put on it the worse it became, and the author explained in his paper how he thought this occurred. Dr. Stead expressed the opinion that the purest steel castings, when initially sound and properly made and heat-treated, gave pieces which were equal in good properties in every direction. But in proportion as the non-metallic inclusions increased, bending tests indicated a proportional weakness in all directions. The less the amount of non-metallic inclusions, under a given extension by hot rolling, the better was the steel in the cross direction. The higher the proportion of non-metallic inclusions, the worse became the resistance to bending in the cross direction. The worst case of weakness of this kind which he (Dr. Stead) had found had occurred in a specimen of wrought iron. Here Dr. Stead showed a number of samples and stated that the cross-section samples of wrought iron only bent 5 degrees before breaking, whilst Armco iron could be bent both longitudinally and in the cross direction to 180 degrees. Commercial billets and steel bars containing from 0·07 per cent. to about 0·3 per cent. of carbon, and 0·07 per cent. of sulphur, bent longitudinally through 180 degrees, whilst in the cross direction they broke on bending from 0 degrees to 90 degrees, according to whether or not the layers of inclusions traversed the test pieces at right angles to the direction of bending; and one might have bends in cross direction varying from 0 degrees to 90 degrees obtained in specimens cut from the same billet or rail. As a rule, the lower the sulphide of manganese and non-metallic inclusions, the better were the cross-bends, but no matter how high the sulphides, the bends in a longitudinal direction were satisfactory. The higher the sulphides and inclusions, the more closely did the properties of steel approach those of wrought iron. In Armco iron there were practically no non-metallic inclusions, and that iron bent equally well longitudinally and in the cross direction. It seemed probable that if an inclusion was not as plastic as the metal in which it was embedded, the metal during working would flow over on all sides of the inclusion and there might not be a proper welding up after pressing over, a weak point being constituted. Non-metallic inclusions were thus not only bad in themselves, but would lead to unsoundness outside their own area. The author of the paper gave examples of the difference in longitudinal sections of rolled and hammered bars. He (Dr. Stead) supplemented these by drawing on the black board cross-sections of a square ingot, showing how the blowhole segregations were distributed at intervals at fairly equal distances from the outside. In rolled 2·5-in. square billets they remained in the same relative position, but in the hammered steel, they assumed the shape of a star, the four apices of which were at the four corners of the square piece hammered down. In angles rolled down from an axially segregated steel, the flow of the steel was such that the segregate was found concentrated in the inside curve bend; this occurred when the rollers of ingots did not reject the top part of the ingot. It was exceptional to obtain bad cross-sectional tests in heavy forgings, and the reason why, in some instances, a bad cross-section test was obtained whilst it was good in others, was difficult to explain; but the variations might probably be due to the fact that the temperatures at different periods of the treatment, particularly perhaps in the carrying out of the forging operations, were higher at times than at others. Dr. Stead, in conclusion, suggested that the paper by Mr. Charpy should be submitted to the Engineering Standards Committee for their very careful consideration.

Mr. Cosmo Johns, who followed, said he was in complete agreement with the statements made by the author on the influence of hot work upon an ingot, and he thought that all who had experience in the subject would say the same. It was not the amount of work carried out on the steel that was the cause of difficulties, but rather the character of that work. In the extension of a large ingot to make a hollow forging, one could manage to break up the original crystallisation, but could not prevent the boundaries of the crystals from persisting in a given direction. The boundaries contained the major portion of all impurities. If it were possible for the work to be carried out at the same time in all possible directions the difficulties could be overcome. Too much work could not be put on steel, provided the temperature was right. Rolling was the least efficient way of breaking up the original crystallisation, forging was better, and the best would be the carrying out of the work in all directions. He found it rather startling that the author should come forward with his contribution now, rather late in the day, for all steel makers knew the subject dealt with; but, he (Mr. Cosmo Johns) added, that this matter had been put forward in a most clear way, and the author deserved the congratulations of the meeting.

Dr. J. S. Unger said he had only just arrived from the United States, and was afraid he could contribute but little to the discussion. He, however, was able to mention one instance, that of a bloom 16 in. square, the top of which had been cut off, the remainder being divided into three pieces, each of which piece was forged down round in three steps (the successive reductions being 30 per cent., 40 per cent. and 50 per cent.) at three works under a 7,000-lb. hammer, a 15,000-lb. hammer and a 2,000-ton press respectively. The temperature at which the forging was made was the same in all three works, and the pieces were each heated once. They were allowed to cool normally. Longitudinal test pieces were taken from the three portions, or steps, of each piece, and there was very little difference in their physical properties. That obtained under the 2,000-ton press gave, however, slightly better results, which was attributable to the slower work carried out and the better temperature at finishing.

Mr. H. H. Ashdown showed how a forging when drawing down was commenced in the middle portion lost heat at the ends rapidly; the steel flowed over the non-metallic inclusions, confirming, in this, Dr. Stead's remarks. Better results were obtained by starting at the ends.

Sir Robert Hadfield welcomed Mr. Charpy as a new member of the Institution. With reference to Mr. Charpy's test figures, he (Sir Robert) presumed that the tests had been made on the ordinary Charpy test bars; it would be interesting in this connection to know also what were their areas and bending angles. It was important to have the degrees of bending, for he had found that it was not only necessary to have the breaking energy, but also the bending energy. Steel-makers were greatly indebted to Mr. Charpy for his bending tests, and, speaking generally, they were more indebted to France than they were to Germany. He was greatly interested in Dr. Stead's remarks with reference to wrought iron; it was most important to study internal defects, and Dr. Stead had at different times thrown a great deal of light on these. He (Sir Robert) was convinced that most of the trouble met with proceeded from the condition in which were the original ingots, and he was glad that the author confirmed the view that it was not necessary in many instances to start from large ingots, since with small ones better results could be obtained.

Dr. W. H. Hatfield, who followed, said the Institute was greatly indebted to Mr. Charpy for the lucid manner in which he had put forward the subject. This was not at all a new subject, for anyone associated with the treatment of large masses of steel had been long familiar with the facts with which the author dealt. An engineer reading the paper might arrive at the conclusion that work on the material was a disadvantage, and that the metal, as cast, was the better material. Unless great care was taken in the making of a sound ingot, the care bearing on the shape of the ingot, the casting temperature and other factors, there would be defects in the ingot. The forging and pressing operations were not merely mechanical in their effect upon the steel; cast steel was in a very indifferent mechanical condition, and work upon the ingot placed the steel in a very different position from which it occupied before the work was commenced, although the density was not increased by the forging or the rolling. At a recent meeting of the Institute, a discussion had taken place on the question of sulphur in steel, and Sheffield steelmakers looked askance at an increase of the sulphur content, since if that obtained, there would be more manganese sulphide present. Sheffield makers, therefore, made it a point to maintain a low percentage of sulphur. Dr. Stead had found that there occurred occasionally both good and bad benders in heavy forgings; the point was difficult to explain, but he (the speaker) thought there was no need to consider the amorphous theory in connection with bad benders. The author had laid stress upon slag inclusions. If the sulphur were kept low, and a satisfactory heat were maintained in the furnaces, many of the troubles alluded to would not be met with. Experience in Sheffield with cross tests was extensive and not an unpleasant one. He would like the author to complete his paper by giving analyses of the steel dealt with; microsections would also be very instructive.

Dr. Rosenhain said that as Mr. Cosmo Johns had pointed out, work applied in all directions would be the best means to follow, but then there would be no change of shape; cross-rolling gave good tests.

With good pure steel, cross-rolling was not necessary. He confirmed the statement to the effect that it was necessary not only to have a sound ingot in the first place, but also an ingot proportioned to the object to be made from it. The illustrations in Mr. Charpy's paper showed the manner in which the sheaves of original dendrites continued in the steel after mechanical work had been put upon it. In an alloy of iron with carbon, nickel, manganese, &c., the original crystallisation did not consist of homogeneous crystals, but of a series of dendrites, and the concentration of the various contents took place in the shape of sheaves of dendrites. If they persisted, this depended upon the heating. Hot work on the steel or cold work followed by heating, tended to equalise them; they could be removed by proper heat treatment alone.

Mr. E. H. Saniter, referring to the author's table giving reductions in area, for example, 170 in longitudinal tests, and 31 in transverse tests, asked how these figures should be understood; they could not mean 170 per cent. or 31 per cent. The paper would gain greatly in interest if the author was to add figures of tests made upon the ingots as cast without any work having been put upon the steel. Referring also to the figures for impact tests upon bars 24 mm. × 9 mm., showing that under 25 blows the bending angle was 70 degrees, and that for the A′ and B′ samples, under the sixteenth and eighteenth blows, &c., the bending angles were 105 degrees and 107 degrees, respectively, and so forth, he found these a curious set of figures, the bending angles of some steels being so much greater than of others, which in the other tests had given very similar results.

This concluded the discussion, and on the motion of the chairman, the author was awarded a hearty vote of thanks for his contribution.

The Influence of Some Elements on the Tenacity of Basic Steel.

The next paper was the one by Mr. Andrew McWilliam, D.Met., A.R.S.M., Indian Munitions Board, on "The Influence of Some Elements on the Tenacity of Basic Steel." It was taken as read. We reproduce it in full on page 315 of the present issue.

Professor Arnold congratulated the author upon having found time to send this valuable contribution to the proceedings of the Institute. The paper both required and deserved most careful consideration, particularly that of students. It was interesting to note how Mr. McWilliam's curve bore out the old Sheffield curve. It showed the tenacity to be proportional to the carbon, and how the tenacity progressed with the increase in carbon.

Mr. Stromeyer wished to call the attention of the meeting to his own papers dealing with the effect of nitrogen upon steel; this was nearly ten times as great as the effect of carbon. The author did not give the percentage of nitrogen, otherwise the author's formula agreed with his (the speaker's) own. Mr. Stromeyer's experiments had been made on German steel.

Dr. Stead said that Mr. McWilliam's steel was basic open-hearth furnace steel mainly; in that steel there was a very small quantity of nitrogen, which was negligible. Dr. A. Cooper here remarked whether it was not a well-known fact that much of the basic open-hearth steel made in Germany really came from the Bessemer converter. The author was awarded the best thanks of the Institute for his paper.

Report on Hardness Testing: Relation between Ball Hardness and Scleroscope Hardness.

The next paper on the list was the one having the above title, contributed by Mr. A. F. Shore, New York, to which Sir Robert Hadfield had added an introduction and a commentary. We propose to reproduce it in full in a forthcoming issue.

Sir Robert Hadfield, in opening the discussion, mentioned that various Institutions were dealing with these same problems, and expressed the hope that co-ordination of their work would take place. The industrial world was greatly indebted both to Mr. Shore and Mr. Brinell, and hardness testing was now practically on the same footing as chemical analyses in laboratories.

Professor T. Turner, who followed, stated that the Institute was also greatly indebted to Sir Robert Hadfield for starting the subject and for having contributed in this particular case an introduction and a commentary. It was important to arrive at a correlation of the Brinell and Shore tests. Professor Turner reminded the meeting that in 1909 he contributed a paper to the Institute dealing with tests for hardness,* in which he had suggested, as a divisor for converting the Brinell into the Shore scleroscope values, the figure 6, a figure at which he had arrived as an approximate one after having examined a large number of samples of various character, metals and other materials. It was interesting to him to see that in the Appendix I to the paper a figure was stated which was in the neighbourhood of 6, but which varied for various metals. By studying the author's curve (Fig. 3) it would be seen that the softer values corresponded to, approximately, the figure 5, whilst the higher values were over 7; the mean value 6 was, approximately, in the middle of these. The author had suggested that his method measured a value closely associated with the elastic limit, whilst the Brinell test gave an approximation to the tensile strength. In order to correlate the two, it would be well if one could start from a material in which the maximum stress and the elastic limit were the same. A number of alloys possessed this property of having an identical elastic limit and tensile strength, but, unfortunately, with these alloys, one could not test hardness by these methods. It was not possible, therefore, to start from this point which he suggested as an ideal one. Consequently, the present basis for correlation was the curve obtained by Mr. Shore, showing that as the elastic limit varied from the tensile strength, then the value for converting one test into the other must change. This curve and the paper, as a whole, will help to correlate the two tests when a material is known from which to start as suggested above by Professor Turner.

Mr. E. H. Saniter said he had been deeply interested in the paper. It was very desirable to test the higher hardness, and Mr. Shore's was a step in the right direction. The author's claim that his test closely took note of the elastic limit, whereas the Brinell test took note of the tensile strength, took him (Mr. Saniter) rather by surprise; in his own tests he had not arrived at that differentiation.

Dr. Stead said Brinell gave figures and numbers, Sir Robert Hadfield's tables varied from low carbon steel up to high-carbon steel, and he (Dr. Stead) suggested that Mr. J. J. Thomas, the author of the Appendix I to the paper, should work out a variable factor to connect the Shore and Brinell hardness. The Brinell test was not to be relied upon for all steels.

Mr. Cosmo Johns thought the subject was a complex one, surrounded by many theories, and he hoped it would be simplified at an early date. On looking through the paper, one would arrive at the conclusion that in the various tests for hardness, one was testing many properties, not one only. The Brinell test was a most useful test for checking the ordinary tensile tests, and that without destroying the objects dealt with. In regard to Mr. Shore's method, he would hesitate to say what it really did measure. It, no doubt, measured several properties. All present methods did not allow of measuring real hardness at all. When new data were available, then would be the time to call a meeting for giving a final solution to the problem.

Mr. J. S. G. Primrose said that, in connection with Dr. Stead's suggestion to work out a variable factor to connect the Shore and Brinell hardness values, he wished to point out that a table to this effect already existed in his (the speaker's) paper on "Useful Testing Machines." It had been found that the factor not only varied for different material but that the conversion could only be made with any degree of accuracy for different conditions of the same material by the addition of a constant to the product. This meant that the graph connecting the two values did not pass through the common zero point. He called Sir Robert Hadfield's attention to the results obtained by Mr. J. J. Abbott, in the 1915 volume of the Proceedings of the American Society for Testing Materials for several plain carbon and alloy steels, both normal and heat-treated, in which the tenacities of those materials were shown to be connected with the hardness values as well as with one another.

Dr. W. H. Hatfield found the paper an extremely valuable one. With reference to the author's statement to the effect that diamond had enabled him to prove the point definitely that fictitious hardness figures were obtained on hard specimens due to the deformation of the steel ball, which, of course, he (the author) had always suspected, that said Dr. Hatfield, was clearly the situation; the Brinell test was not universally reliable. With Mr. Shore's method it was possible to obtain a more intelligent distinction between various grades of hardness at the higher limits.

Dr. C. H. Desch said he would welcome a paper correlating the machining quality of steel with the hardness test. In non-ferrous metals he had made experiments, and had found no relation between the machining quality and the Brinell number. The term "hardness" covered so many properties that a true definition was wanted.

Sir Robert Hadfield regretted having omitted to call attention to the work on hardness carried out formerly by Professor Turner. When one heard a Brinell hardness number quoted, it was marvellous, he added, what that number called up in one's mind. In regard to a definition of hardness, Professor Unwin had said it was almost impossible to define what hardness was. He further advocated the desirability of co-ordinating the work under this head which was being done at the various institutions.

On the motion of the chairman, both Mr. Shore and Sir Robert Hadfield were awarded a hearty vote of thanks for their communications.

The Standardisation of Tests for Refractory Materials.

The last paper taken at the morning meeting on the 12th inst. was on "The Standardisation of Tests for Refractory Materials," communicated, with an introduction, by Mr. Cosmo Johns, F.G.S., M.I. Mech.E. It deals exhaustively with the analysis of fireclays, raw ganisters, dolomite, magnesite, &c.; the identification of the various forms of silica in silica bricks; porosity, water absorption, specific gravity tests; tensile tests of dried clays, &c. It was read in abstract by Mr. Cosmo Johns, who stated that great advances were being made in this country in the manufacture of refractory materials, and who called attention to the important work carried out in this respect by Mr. Le Chatelier, in France, a work which greatly added to our knowledge. We propose to reproduce the paper in full in a future issue.

The discussion was opened by Professor T. Turner, who said that on a previous occasion he had suggested the importance of laying down a series of simple tests for use by the manufacturer. He was glad to see that both kinds of tests, analytical and physical tests, were referred to in the paper, but analytical tests, directions for the complete analysis of clays, were not wanted as often as what he would call routine tests in the works, these being largely physical tests. The paper said that the physical tests described were simple; these simpler or practical tests were in use extensively as early as 20 or 30 years ago. The shrinkage pattern illustrated was a good and simple one, of standard size, such as was used about 20 years ago in a pottery laboratory when he had charge of the work. The paper states that in the test piece per shrinkage test the vertical lines are marked 9 cm. apart; he (Prof. Turner) took 10 cm. and could easily measure on a milimetre scale the change of length. The tensile test of clay and the method referred to in the paper were those that he (the speaker) followed, but personally he attached little importance to the tensile test of clay. Too much attention was, perhaps, given also to the crushing strength of a single brick, for the strength of brick work was often less than one-third that of the single brick, the bonding introducing weakness. Refractoriness could be tested adequately in a well-equipped

* See ENGINEERING, vol. lxxxvii, page 835.

laboratory with an electric furnace and a good pyrometer. The standard rate of heating, a point in the paper, he regarded as a simple method of measuring refractoriness. The paper did not mention the transverse test; this connected tenacity and crushing strength. For the transverse test he took a test bar 1 in. square, 10 in. long, supported at a distance of 6 in. with a bucket suspended from the centre for applying the weight. He could easily see whether the clay had been baked at the correct temperature.

Dr. Stead found that the methods of testing described in the paper were practically the same as those he had been following for many years, but for the analyses of the samples, instead of 1 gramme he used 2 grammes. His (Dr. Stead's) method of testing transversely was very simple; he put a supported 9-in. brick under a Brinell machine and thus tested it rapidly.

Mr. Ridge said he was interested in grog bricks. The paper stated that for the determination of normal refractoriness a representative sample of the material was chipped or shaped into the form of a cone about 1½ in. in height; this could not be done with grog bricks. The brickmaker used a testing cone which was different from that of the user, and the shape of the cone should be defined. The paper stated that for the refractory test under load the test piece was cut from the brick and ground to a rectangular block 3½ in. long by 2 in. in cross section; but as there was a standard brick in this country he asked why the whole firebrick could not be tested, since the character of the brick might be destroyed by the cutting. It meant an increase in labour, in machinery cost, &c., which bore no ratio to the result to be obtained. Users, makers and testers were making a number of tests; the results were pigeon-holed and were of no avail in the case of a neighbouring firm who were manufacturing the same class of bricks as those which had actually been tested. The results obtained should become public property, and the interchange of knowledge in this respect would be generally beneficial. He put that point strongly before the Refractories Committee for their serious consideration. The question of bonding material required also their careful attention. The subject was one of primary importance to all metallurgists, and a further discussion should be held upon it.

Dr. Rosenhain said that the advances made in metallurgy demanded a constant improvement in refractories, and the making on these of more accurate tests than obtained in the past. What was required, besides the test for everyday routine work, was a standard or reference test which could be carried out in a great laboratory where all refinement was possible.

Dr. J. S. Unger stated that he had been greatly interested in Mr. Cosmo Johns' paper. He had been conducting a large amount of work in the testing of bricks, having felt for a long time that many of the tests did not give information of much value to the user. As an example, he would add that the bricks at the top of a blast furnace were submitted to extreme variations in temperature, when icy-cold material was being charged into the furnace and came in contact with the bricks. Lower down they were submitted to slag penetration and to mechanical abrasion. A test made for a brick which was located at the bottom of the furnace afforded no indication of value for those to be used higher up. A chemical analysis could only in a general way give an indication of the quality of a brick. If from a blast furnace which had been running for a number of years and had produced several millions of tons of pig-iron the bricks were removed and analysed, their ultimate chemical composition would be found very different from the one they had originally. The alumina might be practically unaltered, the iron content would have increased to double and the alkalis increased to seven times; therefore the original composition was not of so great an importance. For the bricks at the top, a spalling test should be made to correspond with an ice contact and a temperature of 500 deg. Silica bricks in the open-hearth furnace failed from two causes, spalling and crushing. At the roof the bricks spalled away or crushed away. (He was, he added, referring to basic open-hearth practice.) The spalling test on 25 bricks from the same wagon load would lead to a discard of 9 per cent. to 40 per cent. Therefore the spalling test was an important one to consider, and the crushing test was of the same nature. In this latter test the brick was heated from 1,300 deg. C. to 1,800 deg. C., and was crushed under a pressure of 800 lb. to 4,000 lb. per square inch at 1,350 deg. C. He also took normal slag, which he placed on the brick, heating both to a normal temperature, measuring the depth of penetration of the slag. But the slag running occasionally over the edges, he made a hole 2½ in. in diameter in the brick in which to put the slag. But the brickmakers objected to this, stating that it destroyed the texture of the brick. He then placed on the brick a ring which resisted the action of the slag; this surrounded the slag, and the method was the one now followed for ascertaining slag penetration. He used basic open-hearth slag, standard blast furnace slag, and also standard heating slag, in these tests. All the tests made should closely resemble actual service conditions. The silica bricks should be subjected first to visual inspection, then one should be taken in, say, 1,000 for the crushing test and the spalling test. The crushing test of the silica brick is made hot and Dr. Unger had adopted the temperature of 1,350 deg. C., which was a fair average temperature.

On the motion of the chairman, the author of the paper was heartily thanked for his communication, and the meeting then adjourned until the afternoon.

Some Experiments on the Reaction between Pure Carbon Monoxide and Pure Electrolytic Iron below the A1 Inversion.

The first paper taken at the meeting of Thursday afternoon, the 12th inst., was the one having the above title, by Professor H. C. H. Carpenter, F.R.S., and Mr. C. Coldron Smith, M.Sc. It was read in abstract by the former. In this, the authors showed that the action of pure carbon monoxide on pure iron below the A1 inversion gave rise under certain conditions to a substance they called x for the present, and which was almost certainly a carbide of iron. The presence of sufficient carbon dioxide in the gas completely removed or inhibited the formation of x. The addition of hydrogen to carbon monoxide favoured the production of x by preventing the formation of a solid oxide phase. The authors found that the micrographic and chemical characteristics of x were very similar to those of cementite, Fe_3C, in particular to the form of cementite obtained by Byrom (and identified by Stead), by the action of blast furnace gas on pure iron, wrought iron and mild steel. By the reaction between carbon monoxide and iron at 650 deg. C. carbonaceous products were formed in the majority of cases, containing iron, carbon and oxygen. The formation of a carbide of iron—if carbide it was—in the authors' experiments below A1 was perfectly consistent with the widely accepted opinion that free iron and free carbon were the stable phases of the iron-carbon equilibrium in this temperature range.

Dr. Stead, who opened the discussion, said he had read the paper with great pleasure and was proud to think that the little work he had carried out formerly in connection with Mr. Byrom had led to such a voluminous research as that of the authors. Every single research would seem, therefore, to be the beginning of greater things. What had led him (the speaker) to carry on his own research in the matter was the discovery of a soft iron plate in the flue of a blast furnace where it had remained for many years, a part of the plate having been converted into the mysterious x substance, or Fe_3C. He had doubted whether there were other carbides present, and the question was not yet settled even now. In view of the fact that the change in that plate had been going on for many years, there was considerable evidence that the carbide was very stable. That the addition of hydrogen to carbon monoxide favoured the production of x by preventing the formation of a solid oxide phase was a very important discovery. In regard to the authors' gas analysis after dissolving x in hot hydrochloric acid, Dr. Stead asked whether they had tried with Fe_3C by other means. He believed that a research of that kind would yield very interesting additional information. He acknowledged the value of the very painstaking work carried out by the authors.

Professor Arnold found the paper to contain a large amount of suggestive data and to be free, except, perhaps, in one respect, from controversial matter. He disagreed with the authors in their statement to the effect that the formation of a carbide of iron below A1 was consistent with the opinion that free iron and free carbon were the stable phases of the iron-carbon equilibrium in that temperature range. This, Professor Arnold thought, was a misleading paragraph. The temperature might vary by a hundred degrees above this range and did not come in.

Dr. W. H. Hatfield congratulated the authors on their very interesting work, a work which they had so carefully put together and which was not controversial. He thought that one might expose iron containing carbide for many years, even for an indefinite period, at 650 deg. C. without dissociating the carbide. Carbide and iron were the stable phases of the carbide-iron system; pure carbide was stable at high temperatures.

Colonel Belaieff and Dr. C. H. Desch found the paper of great interest. It gave the basis for future research. The latter thought it might throw light upon a mass of native iron found in Greenland, to which attention had been called by Dr. Benedicks.

In the course of a brief reply, Professor Carpenter said that in writing the paragraph referred to by Professor Arnold all he had in mind was that the iron and graphite phase was the stable phase and the iron and carbide of iron the meta-stable. A full reply would be given in a written contribution to the proceedings.

On the motion of the chairman, the authors were given a hearty vote of thanks for their contribution.

A Method for the Prevention of Growth in Grey Cast Iron.

The next paper on "A Method for the Prevention of Growth in Grey Cast Iron" was contributed by Mr. J. E. Hurst, who read it in abstract. In this the author stated that the primary cause of growth in expansion of grey cast iron when subjected to repeated heatings in an oxidising atmosphere was the presence of the free graphite plates, which allowed of the entry and penetration of the oxidising gases into the interior of the iron. Malleable cast irons, in which the free carbon exists in the nodular form of annealing carbon, did not grow. This was the result of the fact that the graphite in these irons did not present a continuous path for the penetration of the oxidising gases into the interior of the brass. The removal of the free graphite from the exterior surface layers of the cast iron would appear to be an ideal method for preventing the penetration of the oxidising gases. Such a method would amount to the production of a skin or "case" of decarbonised material round the cast iron, which would effectively prevent the entry of the oxidising gases. The paper indicated the possible methods of doing this, and stated that the production of such a "case" around cast-iron articles would be of considerable service in the prevention of growth under many circumstances—for example, in the manufacture of dies and permanent moulds for iron and non-ferrous metals.

Dr. W. H. Hatfield disagreed with the author's views and looked with disfavour upon the submitting of grey cast iron to the heat treatment indicated, and he (the speaker) thought that if the author had referred to Professor Carpenter's work on the subject his investigations would have taken a different line. The exposure of grey cast iron to high temperatures was ruinous.

Mr. Young disagreed with the author's statement to the effect that the total growth of grey cast iron was roughly proportional to the extent of silicon present in the original irons, since total growth could be altered apart from the silicon. The paper by Professor Carpenter had led him (the speaker) to believe that the penetration of the oxidising gases was not due entirely to graphite. He asked what was the depth or thickness of the protective case, and if it was on both sides or only one. He would

have liked the paper to give a micrograph of the metal before the heating had taken place. The author had stated that in one of his experiments the whole of the silica precipitate from the silicon was white and flocculent, this being confirmatory evidence of the absence of internal oxidation; but just previous to that he referred to the low total carbon present. The carbon content not being right there could not be therefore the confirmatory evidence alluded to. The author had also mentioned a method by which graphite might be removed without the subsequent production of cavities, there being superficial decarburisation and oxidation of the graphite, followed by liquation of the phosphide eutectic into the remaining cavities; but in a former paper he had described phosphorus as unnecessary. He would therefore now seem to have reached an opposite conclusion.

Dr. Stead said he was interested in one point of the paper, and asked the author for samples to see what the phosphide of iron was like. On annealing cast iron there occurred a ring a little distance from the outside which, although it looked like phosphide of iron, he found to be carbide. But on the outside carbon being removed, the phosphide was in solid solution; there was no free phosphide, which so far confirmed Mr. Hurst's statement. On examining Mr. Hurst's sample he found the material was phosphide, and phosphide in solid solution. On the oxidation from the outside the iron oxides and the phosphide gradually contracted into the middle. It was satisfactory to find that the occurrence was phosphide and not carbide. He would like the author to determine by actual trials whether or not growth did stop; it might be possible that growth did actually occur.

The chairman stated that the first experiments in regard to growth of cast iron were made by Mr. A. E. Outerbridge in the United States, and asked the American members present whether they would contribute to the discussion.

Dr. J. S. Unger here said that full particulars on Mr. Outerbridge's experiments would be found in the Proceedings of the American Institute of Mining Engineers issued in the early spring of last year.

Mr. Hurst, in replying to the discussion, said he put forward his methods for use only in some instances, with judicious care, when he hoped that they would prove to be of great value. He totally dissented from the views that had been put forward, since growth could be prevented, and it was very unfortunate that he could not exhibit at the meeting the actual samples upon which he had worked, as these were in use at the present time. He would give further details in a written reply. In reply to Mr. Young he would state that the depth of the case was $\frac{1}{16}$ in. on either side, and $\frac{1}{16}$ in. for the core.

On the motion of the chairman the author was awarded the thanks of the meeting for his paper.

Note on the Warping of Steel through Repeated Quenching.

The last paper taken at the meeting of the afternoon of Thursday, September 12, was the "Note on the Warping of Steel through Repeated Quenching," by Mr. J. H. Whiteley, who read it in abstract. In this, the author stated that a cylindrical piece of soft steel cut from a round bar of about 3·5 in. in diameter was heated to a blood-red heat (700 deg. to 800 deg. C.) and served to warm a small tank of water used for moulding purposes. About 200 heatings and quenchings were given during a year, and after four years of this treatment the cylindrical piece had gradually become nearly spherical in shape. This confirmed a statement made formerly by Dr. Stead, to the effect that "if an oblong bar of soft steel were to be heated and cooled a sufficient number of times under proper conditions, it would eventually assume a globular shape."

Dr. Stead was greatly interested to find that the author's actual experience had confirmed what he had anticipated would take place as the result of quenching a cylindrical piece of steel a number of times. The placing of a short cylindrical piece of steel in the furnace, reheating and quenching it halfway up repeatedly would convert that cylindrical piece into a piece of conical shape. Heating and quenching under the requisite conditions was resorted to frequently by engineers for straightening out various pieces. Every time a bar was quenched in water its shape changed to a small extent it was true, but the bar was not of the same shape as before the treatment, and it was quite obvious that the treatment would also lead to distortion in certain given conditions.

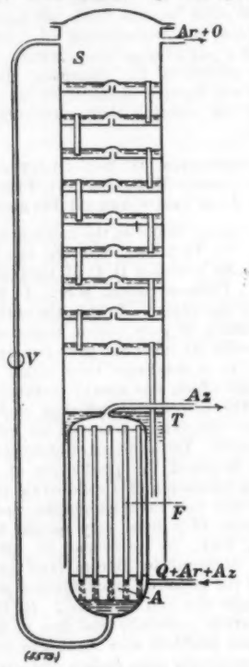
The author received the thanks of the meeting for his communication.

(To be continued.)

NOTES.

The Preparation of Argon.

In a paper recently read before the French Society of Civil Engineers M. Georges Claude stated that experiments made by M. Gervaise at the laboratories of the French Thomson-Houston Company had shown that a very great advantage was obtained by replacing by argon the nitrogen hitherto used in high efficiency lamps. Thus the filament of a 50 c.p. lamp when surrounded by argon took 2 per cent. less current and gave 20 per cent. more light than when the bulb was filled with nitrogen. Argon, M. Claude stated, owed its superiority to its high density, its molecular weight being 40 in place



of the 28 of nitrogen. Presumably, krypton and xenon would be even better for the purpose, since krypton has twice the density of argon and xenon is one and a-half times as dense as krypton. Unfortunately, however, these two gases are exceedingly rare, the proportion of krypton in air being 1 part in a million, whilst xenon forms only 1 part in 30,000,000 or 40,000,000. On the other hand, argon constitutes about 1 per cent. of ordinary air, and in view of its superiority over nitrogen as a bulb filler a commercial demand for the pure gas has arisen. This is obtained by a process of rectification, the air being liquefied and its constituents separated from each other along the same lines as alcohol can be concentrated from a dilute solution. The separation of argon in this way presents, however, special difficulties since it is less volatile than nitrogen and more volatile than oxygen. Thus whilst it is easy to concentrate the argon until it forms 5 per cent. to 10 per cent. of a mixture of which the remainder is oxygen and nitrogen, there are difficulties in effecting a further separation. The apparatus worked out by M. Le Rouge for this purpose is shown diagrammatically in the illustration. The mixture above referred to, containing 5 per cent. to 10 per cent. argon, is fed under pressure into a chamber immersed in a mass of liquid oxygen at the base of a rectification column. Here part of the gas fed in, condenses in the bath of liquid and part passes up through the pipes shown to the escape pipe T. In these pipes further liquification occurs and drains back into the bath below. What finally escapes at the outlet T is pure nitrogen. The mixture which collects at the bottom of A contains all the argon, all the oxygen, and very little nitrogen. By means of the pipe shown on the left a regulated supply of this liquid is allowed to pass up to the top of the rectification column through the valve V. When a mixed liquid evaporates, the composition of the gases given off is not in general the same as that of the parent liquid. Thus freshly liquefied air contains 21 per cent. of oxygen, but the gases evaporating off it contain only 7 per cent. of oxygen. The same principle applies to the mixture of liquid argon and oxygen. This liquid enters the top of the rectifying column at S and drains down from compartment to compartment through the vertical pipes shown. At the same time there is a back current of escaping gases passing upwards from compartment to compartment through the central openings and out under the bells shown. On the principle just explained, this escaping gas is much richer in argon than the liquid in the same compartment, and as it passes up the column the proportion of argon continually increases, whilst conversely the proportion of argon in the descending liquid diminishes, so that practically pure liquid oxygen is collected at the bottom of the column, whilst at the top the escaping gases contain 75 per cent. to 80 per cent. of argon and only 25 per cent. to 20 per cent. of oxygen. In order to get the argon pure this residual oxygen is got rid of by combustion with hydrogen. The pure argon thus obtained freezes to a wax-like solid when submitted to the temperature of liquid nitrogen, viz., — 195 deg. C. At atmospheric pressure liquid argon has the remarkably high specific gravity of 1·41.

Compressed Air Agitation of Water to Prevent Ice Formation.

Heavy ice forming up-stream of the Keokuk Dam across the Mississippi River, says *Engineering News Record*, New York, caused serious trouble during the winters of 1915–16 and 1916–17. In the first winter, heavy floating ice battered out one of the spillway gates, and in the following winter a steady pressure of thick ice caused permanent deflections in a number of the many gates spanning the spillway openings. To prevent the recurrence of such conditions, early in the winter of 1917–18 a system was devised whereby dry air under pressure was forced out in front of each gate, so agitating the water there as to prevent the formation of ice. We described the dam and power plant in two former issues (see ENGINEERING, vol. xcvi, pages 675 and 712). Dealing with the device to prevent the ice formation, our American contemporary states that the tests were made on ice ranging from 10 in. to 22 in. thick; the work which a very small amount of air could accomplish when discharged under a considerable depth of water was surprising. The air does not bring up warm water from below, but it creates a circulation which keeps the water always at a temperature above freezing, passing continuously by the ice edges. A column of water rises with the air and flows radially from the point where the air bubbles break the water surface. It was found that a little less than 2 cub. ft. of free air per minute would keep an area of 20 ft. in diameter open, if discharged vertically upward at 18 ft. depth, in a period of about four days. The system is capable of furnishing a maximum of 2 cub. ft. of free air per minute to each gate. The compressor was designed to supply the maximum demand on the dam, and in addition to furnish as much air again for use in the power-house. The installation was completed and ready for operation after the lake froze over, early in December, 1917. Its total cost was well within the estimate of 9,500 dols. The pipe main is 2 in. diameter from the power-house for a distance of three-fifths of the length of the dam, and $1\frac{1}{2}$ in. from that point to the last spillway. It was designed to carry 2 cub. ft. of free air per minute to each of the 119 spillways, with an initial air pressure of 80 lb. and a terminal pressure of 55 lb. Six expansion joints having a total travel of 90 in. are provided for the total length of the main,

which is 4,270 ft. To dry the air, an after-cooler capable of removing two-thirds of the moisture content of the air flowing through it, was installed in the pipe line just before it leaves the building. It cools the entering air by cold water coils and removes the water by condensation. As a further aid in drying the air, the system was designed to reduce the air pressure from 125 lb. to about 75-lb. gauge, through a pressure-regulating valve. This valve has not yet been operated as an agent in drying the air, but to secure variable pressures in the main on the dam, as an aid in adjusting the whole system to climatic changes, the after-cooler drying the air sufficiently to prevent freezing in the most severe weather. A ¾-in. needle valve at each spill-way controls the flow of air through the ¾-in. pipes which discharge the air; the latter are set so that they discharge vertically upward about 1 ft. in front of each gate and normally at a water depth of 10 ft. This produces a semicircular area of open water in the front of the gate. It was found that the air when discharged at an 18-ft. depth was too effective for convenient regulation by the small valves. The open-water areas have been at all times under the easy control of the small needle valves at the top. These valves seldom need adjustment more than once a week, since a great deal of the regulation can be effected by the pressure regulating valve in the power-house. The installation through the extremely severe weather last winter was most successful, and the maximum capacity of the system has proved sufficient to melt ice from the face of the icefield faster than it can move toward the dam under ordinary expansion.

INDUSTRIAL NOTES.

THE Director of the Department of Labour Statistics states in *The Labour Gazette* that in August the cotton, jute and certain other textile industries continued to work short time, but most of the other trades were fully employed, and in many cases worked overtime. The upward movement in rates of wages continued and changes affecting over 1,700,000 workpeople and resulting in an increase of about 300,000*l.* a week were reported as having been granted during the month.

Trade unions with a net membership of 1,137,520, excluding those serving with the forces, reported 0·5 per cent. of their members as unemployed at the end of August, compared with 0·6 per cent. at the end of July and 0·5 per cent. at the end of August, 1917.

Of the 3,921,878 male and female workpeople insured under the National Insurance Acts, 1911 to 1916, the number unemployed at the end of August was 26,024 (or 0·66 per cent.), compared with 0·67 per cent. in the previous month and 0·69 per cent. a year ago. For males and females separately the percentages unemployed at the end of August were 0·34 and 1·31.

The average weekly number of vacancies notified to all Employment Exchanges for the four weeks ended August 9, 1918, was 40,010, as compared with 44,785 in the previous five weeks, and with 32,626 in the four weeks ended August 8, 1917. The average weekly number of vacancies filled for the same period was 30,279, 33,950 and 24,915 respectively. The number of workpeople remaining on the live register at August 9, 1918, was 27,132 men, 46,674 women, 7,454 boys and 6,704 girls—a total of 87,964.

The changes in rates of wages (including war bonuses) reported to the department as having been granted in August resulted in an increase of about 300,000*l.* in the weekly wages of over 1,700,000 workpeople. No decreases were reported.

The principal changes recorded were increases, under awards of the Committee on Production, to men and boys in the engineering and shipbuilding trades, amounting to 3*s.* 6*d.* per week for those 18 years of age and over, and 1*s.* 9*d.* per week for those under 18. Similar increases were granted to men and boys in a large number of other metal trades, and in the chemical and explosives trades. Other important changes included further advances to woollen and worsted operatives in Yorkshire, to women employed by tram-way and omnibus undertakings, and to building trade operatives in Scotland.

The number of trade disputes beginning in August was 84, and the total number of workpeople involved in all disputes in progress was 227,800, as compared with 96,900 in the previous month, and 63,700 in August, 1917. The estimated total aggregate duration of all industrial disputes during the month was 707,900 days, as compared with 582,500 days in July, 1918, and 332,700 days in August, 1917.

The Executive Committee of the National Alliance of Employers and Employed issued last Friday a manifesto stating that they have had under consideration the increasingly serious industrial unrest in this country and the tendencies which it reveals. One of the most significant points which impresses itself upon the committee is that in many of the recent strikes the demands were conceded almost as soon as the strike had been called. In explanation of this, it is not sufficient to argue, say the committee, that the circumstances of the times forced the concession of the demands, irrespective of the measure of justice behind them. In the mind of the committee, if that argument held good, it would reveal an even graver state of things than actually exists. It is obvious, on the other hand, that matters should not be allowed to drift until the workers are forced to the conclusion that the strike weapon is the only one by which they can establish their claims. It would, indeed, be difficult, the committee further state, to condone a system under which demands are ignored as long as the workers remain at their posts, whilst these demands are conceded as soon as they down tools.

The committee are convinced that the first essential to be aimed at is a definite and consistent Government policy, a policy not of drift but of prevention, a policy that shall be capable of direct and effective application before strikes occur, that will meet after-war conditions as well as present needs and that will either convert or destroy all the disruptive groups in the country.

The committee are convinced that the end in view can only be attained and industrial reconstruction carried out adequately if employers and employed are brought together on terms of equality to formulate and to give effect to an industrial reconstruction policy in conjunction with the State. They suggest to the Minister of Reconstruction, the Minister of Labour, and the Minister of Munitions that results of incalculable value could be achieved by the calling of a round-table conference of representatives of employers and employed, who are associated in this and other organisations with similar aims; representatives of employers' associations and trade unions as such; and representatives of the Government departments concerned. Industrial reconstruction is a matter for the parties most directly concerned, the employers and the employed, in conjunction with the State as representing the interests of the community.

The Committee on Production will be hearing cases in Glasgow next week, among which is a claim by the Ship-constructors' and Shipwrights' Association for a wage of £5 for a normal working week.

A new list of certified occupations was issued on the 17th inst., under reference R. 136 (Revised), superseding the former List R. 136. The revised list comes into force on September 26, 1918. The former distinction between single and married men has been discontinued; a shorter period of qualification has been fixed; and numerous alterations have been made as to the occupations which are certified and the ages to be attained to qualify for inclusion. With a few exceptions the list covers all men of the new military age of all medical grades who are engaged in the occupations mentioned in the list, including directing heads of businesses, managers, and departmental managers. A man claiming to be in a certified occupation must show: (i) that from January 1, 1918 (instead of August 15, 1915) he has been employed or engaged as his principal and usual occupation in an occupation named in the list, and (ii) that he complies with the conditions as to year of birth and medical grade which apply to his particular occupation.

In many occupations the raising of the ages in the list automatically cancels, on the 26th inst., Tribunal certificates granted on the ground that the holder was in an occupation certified by the former list. Any man whose certificate has been so withdrawn is made liable for military service subject to his right to apply to the Tribunal for renewal on grounds other than that of certified occupation. Such application must, under the current regulations, be lodged not later than the 30th inst., being the fourth day after the expiry of the former certificate. Under the current instructions issued by the Ministry, men of the new military age who are within the terms of the new list of certified occupations are not for the present to be summoned for medical examination and therefore need not apply to a Tribunal. Any such man who receives such a summons should return it to the office of issue with particulars of his claim to be in a certified occupation, as stated in previous announcements. Inclusion in the list does not in itself confer exemption, but each man must obtain an individual certificate from a Tribunal, and exemption is not necessarily granted. Instructions have, however, been issued that discrimination must be exercised in dealing with applications by men who establish that they are in certified occupations, and that these applications are not to be opposed unless in a particular case there are definite and specific reasons for contending that it is no longer necessary in the national interests that the man should remain in civil employment.

Copies of the list may be obtained from H.M. Stationery Office, either directly or through any bookseller or newsagent. The price of the list is 1*d.*; post free, 1½*d.*

THE CHAIRMANSHIP OF VICKERS, LIMITED.

MR. ALBERT VICKERS has written as follows to the directors of Vickers, Limited:—

"My dear Colleagues,—I shall be four score years old on September 16, and shall then have spent sixty-four years of my life with the company and the old family business from which the company sprang. I may claim without presumption to have had a very large share in the work which brought about the expansion of "Vickers" to its present position, and its fortunes have always been bound up with my own. The time has unfortunately come when my health no longer permits me to take the share in the management that a chairman should, and I have come to the conclusion to resign the chairmanship. I ask you to take this letter as my resignation as from September 16 next, with my most heartfelt thanks to you one and all for the support and help you have always given me. I am sure you all know that my interest in the company's affairs remains as keen as ever and that though my bodily energies have given out my mental energy will always be at your service for consultation and advice."

After careful and sympathetic consideration of the above letter, the following resolution was passed unanimously:—

"Although the directors most deeply regret the resignation of the chairmanship by Mr. Albert Vickers, they nevertheless recognise that in view of his advanced age and the state of his health, they cannot do otherwise than follow his wishes, and they therefore accept that resignation as from September 16 of this year. In doing this, the directors wish to place on record the heartfelt expression of their unbounded admiration of the splendid work which Mr. Albert Vickers has done in the service of the company, and thereby in the service of his country. During the sixty-four years which Mr. Albert Vickers has, as he says, spent 'with the company and the old family business from which the company sprang,' the business has, as a matter of fact, expanded from one of relatively small dimensions to the position of perhaps the greatest industrial concern in the country, and certainly by far the leading concern of its kind. This expansion forms an unprecedented record of continuous growth of manufacturing capacity and business interests, and of ample resources with which to support them, and the directors recognise throughout the whole of this wonderful history of the company, the great guiding mind, the sure judgment, the unfailing courage, and the unerring foresight of their present chairman.

"The directors are glad to think that although Mr. Albert Vickers is resigning the chairmanship, they may nevertheless at all times rely upon him for consultation and advice, and they wish him with all their hearts many years of good health for the enjoyment of the relative rest from the cares of business, upon which he has now resolved to enter."

Resolved: To present a copy of Mr. Albert Vickers's letter and of this Minute, suitably illuminated and framed, to Mr. Albert Vickers on his eightieth birthday, September 16, 1918.

Resolved: To appoint Mr. Douglas Vickers chairman of the company as and from September 16, 1918, upon which date Mr. Albert Vickers vacates the chairmanship.

ACETONE FROM KELP.—The kelp industry of the Pacific Coast, which was carried on mainly for the purpose of extracting the haloids, iodine and bromine, and lately also potash, from the tangs, has in the last years received a new impetus by the demand for acetone. The Hercules Powder Company, of California, has put down a plant at Potash Bay, near San Diego, to deal with the giant kelp of that coast, for the production of acetone and potash, and also of ethyl propionate and ethyl butyrate, which are valuable substitutes for amyl-acetate. The works cover 30 acres, and 1,000 men are being employed; in 1917 about 24,000 tons of kelp were cut per month, but one rather feels doubtful whether that rate could be maintained for a long period. The acetone manufactured is said to satisfy the stringent tests of the British specifications.

EFFECTS OF CHLORINE IN TAR DISTILLATION.—The presence of even very small percentages of chlorine in tar distillation plants is generally dreaded, but there are few actual data on the corrosive effects of the chlorine and on the nature of the compounds which are particularly deleterious. Some figures were recently communicated by Mr. L. Crawford, late of the Littleburn Colliery Tar Works, Durham, to the *Chemical Trade Journal* for the purpose of inducing others to come forward with their experience as to the correlation between the chlorine percentage and the corrosion of the still domes and other parts of the plant. Crawford analysed seven tars from various types of coke ovens with horizontal and vertical retorts. The chlorine percentages ranged from 0·0053 up to 0·148; in one case 0·226 per cent. of chlorine was found, though the bulk sample did not contain more than 0·111 per cent. Mr. Crawford does not consider that these and other observations and experiments of his, extending over more than a year, justify him to draw any general conclusions; but a percentage of 0·1 of chlorine in tar seems to be the safe maximum tolerable.

PAYMENT BY RESULTS.

To the Editor of Engineering.

SIR,—It seems strange that a system which has all the inherent good or "bonus" that the premium bonus system has, should require the pressure of a Governmental edict to make it popular with the workers who are going to get ninepence out of every shilling saved!

If space were not so valuable I could tell some amusing stories about engineering works whose adoption of the premium bonus and other "formula" methods has resulted in the whole energy of the plant being employed to keep the "system" going, instead of concentrating first and last upon a large and economical output.

One plant was managed so harmoniously that every man employed got paid every penny due to him down to the time of receiving his wages. Also the firm had a splendid reputation for accuracy and for quick deliveries. Not having wisdom to let well alone, the junior partners desired to get "a move on." They introduced the whole paraphernalia of stop-watches and square pegs in round holes, and the first thing they did was to attempt to stop two and a-half days of the workers' pay, which caused a strike. Then a compromise was effected on this head and payment by results introduced. Well it was quite plain that every job was taking twice as long to do as under the old system.

Taking everything into consideration, if the proprietors had been as keen on making money as they were in keeping their little army of tabulators and ticket sorters employed, they could have doubled their income from the plant.

I would be the last to deny that engineering works would not find it an advantage to adopt a method of payment by results. The problem is what is the method; and how are you going to apply it?

In every works where the premium bonus system is giving satisfaction to masters *and* men, I firmly believe that given a just management which insisted always on justice, a greater output could be obtained and the plant put to a better use by dispensing with the bonus.

The adoption of this method of rewarding the workers has for some years struck me as a confession of failure on the part of those adopting it to get the maximum economical output from their plant, and at the same time keep the spirit of loyalty and enthusiasm alive amongst the workers. And, oh! especially in this day of days, adopt no system or formula which will tend to increase the power of those disruptive workers who have yet to learn that if we do not do more than we are paid for doing, we will never be paid more for what we do.

Yours faithfully,

M. MACPHERSON.

18, Cambridge-street, S.W. 1.

"COAL SAVING BY SCIENTIFIC CONTROL OF STEAM BOILER PLANT."

To the Editor of Engineering.

SIR,—With regard to the letter of your correspondent, Mr. E. W. L. Nicol, in the issue of September 6, 1918, concerning the use of coke, the "somewhat disparaging reference" applies only to the quality of the coke, and not to the question of the relative advantages of coke as compared with coal. I have had considerable experience in burning coke and coke breeze for steam generation, and my opinion is, generally speaking, that coke is a much more efficient fuel than coal. On a "Lancashire" boiler, for example, it is quite possible to burn 22 lb. of coke per square foot of grate area per hour with 6-ft. grates, giving 14 per cent. to 15 per cent. CO_2, continuously without smoke, and to evaporate 9 lb. of water per pound of coke; that is to say a "Lancashire" boiler, 30 ft. by 8 ft. with 6-ft. grates will burn, say, 835 lb. of coke per hour and evaporate, say, 7,515 lb. of water per hour. A well-equipped "Lancashire" boiler plant with superheaters and economisers can be worked easily at 80 per cent. efficiency with coke, and it is possible to run on 85 per cent. efficiency. A mixture of half and half coke and coke breeze will give about 8 lb. of water per pound of the mixture at the same rate of combustion, namely, 22 lb. of mixture per square foot of grate area per hour.

It may interest Mr. Nicol to know that some time ago we reorganised a "Lancashire" boiler plant in the north of England, changing the fuel from coal to coke, and obtaining 25 per cent. saving in the fuel bill, obtaining month after month average figures of about 9·25 lb. of water evaporated per pound of coke, an astonishingly good result.

These favourable figures, however, in the first place only apply when the plant is reorganised on the proper lines for the burning of coke and coke breeze, and the mere substitution of coke for coal does not necessarily give favourable results, if the conditions are not suitable. Many firms have had the most disheartening experiences in this respect because they have been in complete ignorance of the working conditions of their own plant.

Secondly, the coke and coke breeze must be reasonably free of moisture and, as I stated in the article, this is one of the chief difficulties in the way. An average good sample of coke contains, say, 12,000 British thermal units to 12,500 British thermal units per pound and about 5 per cent. water (certainly not over 8 per cent.). There is, however, no guarantee, at any rate in most parts of the country, that the coke and coke breeze is not absolutely "water logged" containing 20 per cent. of moisture. In this condition 1 lb. of coke will evaporate about 4·5 lb. of water instead of about 9 lb., the results being hopeless.

The majority of coke and coke breeze on sale probably contains nearer 15 per cent. of moisture than 5 per cent. As I stated in the article, coke is being used to-day as fuel for steam raising, costing 35*s.* per ton with an analysis of 10,000 British thermal units per pound, 15·5 per cent. ash, and 14·5 per cent. moisture. The reason seems to be that coke is of a porous nature and easily takes up moisture from excessive quenching or from being rained upon as it is carted about or left lying in stock in the open air.

A further trouble is that in most parts of the country coke is too expensive. Assuming that the coke is of good quality it is no use paying, say, 35*s.* per ton for coke and running the boiler plant at 80 per cent. efficiency when coal of about the same heating value can be bought at 25*s.* per ton and the plant can be ran at, say, 70 per cent. to 75 per cent. efficiency. This is, of course, a question of local conditions, and the whole matter has to be carefully considered, so that the adoption of coke as against coal is by no means such a simple question as it may appear.

There is a most astonishing difference in the price of coke and coke breeze in different parts of the country, even in towns a few miles apart, and in fact a study of the whole question of using coke as fuel presents a most staggering example of the chaotic conditions in industry generally from the point of view of efficiency and organisation. Many corporations, for example, are simply hopeless in their methods, and will give no reasonable guarantee of quality or even of price for more than a few weeks, and will not make definite contracts.

Yours truly,

D. BROWNLIE.

September 16, 1918.

To the Editor of Engineering.

SIR,—I am pleased to read that Mr. D. Brownlie appreciates my remarks on coal and the other fields for improvement in addition to steam generation, still I regret that he does not deal with this subject beyond this point.

I suggest, Sir, that these other matters all relate to the conservation of our national asset—coal.

A paper read before the Institute of Marine Engineers, November, 1916, brought forward very interesting details relating to this subject, and in the subsequent discussion to this paper many instances were given whereby considerable savings could be effected after the steam is generated, some amounting to over 40 per cent. actual saving.

The instance of coke-firing as given by Mr. Nichol is exceedingly interesting, and rather supports our letter to you on centralisation—January, 1916, and later; but there are a few things regarding this instance that one would like cleared up, principally as regards the appliances used to weigh the coke and measure the water together on the method used to determine the amount of steam for draught purposes.

There is a sentence I do not understand, and would therefore like Mr. Nichol to enlighten me on, "When the increase of efficiency due to the superheaters is allowed for, and also the loss in efficiency due to using 3 per cent. of the steam under the fire-bars, the real net efficiency of the plant works out at 86 per cent."

Surely this 3 per cent. should be deducted, as it is required to create the draught to consume the fuel.

Although Mr. Nichol's scheme is a war measure and he is to be congratulated on his results, yet at the same time it would be very interesting to some of us, who from a purely patriotic point of view have been advocating this economy of fuel for years and who take a broader view of this subject—from the miner to the consumer—to know the source of the coal supply and how many times handled to the gas works producing this 200,000 tons of coke, the number of distributing wagons or carts, the size of same, the method of loading and discharge and the number of men employed on this distributing work, together with the added cost of getting rid of the practically doubled quantity of resultant ash due to using coke.

Also the detrimental effect, if any, from the use of damp coke on the heating surfaces, &c.

These answers would then give us something to go on as regards our suggestions in ENGINEERING, 1916, whereby we advocated central stations of huge capacity, modern coal handling appliances direct from the collier (which is the cheapest way to bring bituminous coal) or from wagons loaded at the mine. This coal to be put direct into the distillation plant, by-products recovered together with the gas, the resulting coke, if possible, without quenching to be used at the same place for power production in either steam or gas engines, but for preference the latter owing to the much higher efficiency.

The power for London to be high-pressure electricity or high-pressure gas.

Plants requiring boiling water could have gas engines for their power with the addition of a heater; it is not generally known that with these heaters it is possible to obtain 20 lb. of boiling water per brake horse-power per hour for nothing, excepting a nominal capital charge.

Domestic heating by electricity or gas. The use of raw coal or coke to be abolished.

I am, Sir, Yours faithfully,

JOHN H. ANDERSON.

Purfleet, Essex, September 7, 1918.

BRITISH SHIPBUILDING.—Speaking at the annual meeting of Messrs. R. and W. Hawthorn, Leslie and Co., Limited, Sir H. Rowell said that apart altogether from repairs—a branch of the industry which has from the nature of things increased enormously during the war—new construction in this country, taking both naval and mercantile together, has been during these war years half as much again as during the best year of peace. This expressed in terms of output of merchant shipping would, he estimated, be equal to about 3,500,000 gross register tons per annum, a record of which the country may well be proud.

REINFORCED CONCRETE 3,500-TON DEADWEIGHT U.S. SHIP.

IN a special report to the chairman of the Shipping Board, R. J. Wigg, chief engineer, Department of Concrete Ship Construction, Emergency Fleet Corporation, sums up the conclusions of the Concrete Ship Department as to the advisability of constructing concrete ships, and from this we make the following quotations from the *International Marine Engineering*:—(1) The reinforced concrete ship can be built structurally equal to any steel ship. (2) The available information assures, with all the certainty possible, short of actual experience under service conditions, that the concrete ship will be durable for several years, assuring satisfactory service throughout the probable duration of the present war. (3) The cost of the reinforced concrete ship complete will vary between 100 dols. (20*l.* 16*s.* 8*d.*) and 125 dols. (26*l.* 0*s.* 10*d.*) per ton deadweight, depending upon the number of ships built and the conditions of construction. The cost of the hull only will be between 30 dols. (6*l.* 5*s.*) and 40 dols. (8*l.* 6*s.* 8*d.*) per ton deadweight. (4) The construction of concrete hulls will not interfere with the present programme for the construction of steel and wood hulls in so far as labour or materials are concerned. (5) The Concrete Ship Department has completed the detailed plans for a 3,500-ton concrete ship, so that construction of such ships can start immediately. (6) It is estimated that between 150 and 200 3,500-ton concrete hulls can, if construction is started immediately, be completed by December 31, 1918, totalling approximately 600,000 tons. (7) It is further estimated, if the construction of yards is begun immediately and the construction of hulls of 7,500 tons each commences by June, 1918, that 250 can be completed by August, 1919.

The 3,500-ton Concrete Ship.—The standard concrete ship of 3,500 tons deadweight carrying capacity is of the same size, dimensions and form as the 3,500-ton standard wood ship* except that the sheer line amidships has been slightly altered and no outer keel is fitted. The arrangement, Figs. 1 and 3, page 318, follows closely that of the wood ship, including the number and location of bulkheads. The propelling machinery design for the wood ship has been provided for without essential change in this vessel. The principal dimensions of the concrete ship are as follows:—

	Ft.	In.
Length overall	281	10
Length between perpendiculars ...	268	0
Beam, over shell	46	0
Depth, amidships, on side	28	3
Draught	23	6
Full load displacement ...	... 6,175 tons	

The comparative weights of similar ships built of concrete, wood and steel are given in Table I.

TABLE I.—*Comparative Weights—Concrete, Wood and Steel Vessels.*

——	Concrete.	Wood.	Steel.
Hull	2,500	2,300	1,160
Fittings, outfit and equipment	191	191	180
Propelling machinery	206	206	200
Margin	75	80	60
Ship (light)	2,972	2,777	1,600
Reserve feed	80	80	80
Ordnance	23	23	23
Fuel	300	300	300
Stores	40	40	40
Cargo	2,760	2,680	3,057
Total deadweight	3,203	3,123	3,500
Full-load displacement	6,175	5,900	5,100
Percentage deadweight to full-load displacement	52	53	68·6

TABLE II.—*Stresses in Government 3,500-ton Concrete Ship.*

Condition.	Maximum Bending Moment, Ft.-Tons.	Maximum Tons per Sq. In. Fibre Stress in		Lb. per Sq. In. Fibre Stress in Concrete.
		Deck Reinforcement.	Keel Reinforcement.	
Ship without cargo, hogging	25,175	5·53	2·80*	728
Ship fully loaded, hogging	37,000	5·63	2·95*	766
Ship without cargo, sagging	14,400	1·28	2·63†	270
Ship light with enough cargo in forward hole to trim, sagging ..	11,960	1·07	2·19†	210
Ship fully loaded, sagging	9,400	0·84	1·72†	70

* Keel. † Deck.

Strength of Hull.—The strength of the ship as a girder supported on the crest of a wave amidships, hogging, and also on the crest of two waves, one at each end, sagging, was calculated for five conditions. The same basic conditions were assumed as to length, depth and form of waves and the same method of procedure that is standard practice in calculating the strength of steel

* *Engineer*, vol. civ., p. 90.

ships was followed throughout. The maximum bending moments and fibre stresses in the steel reinforcements and concrete in the various conditions are given in Table II.

Metacentric Height, Stability and Period of Roll.—The metacentric heights in the light (ship without cargo) and full-load conditions are, respectively, 2.15 ft. and 2.2 ft. The best practice at the present time from 5 tons to 8 tons per square inch figured on the same basis as given above for the concrete ship. In addition to the stress due to the ship acting as a girder there is the local stress between frames, where the plating must act as a beam for that space. This action is seldom taken account of in steel ships, but has been given full consideration in the design of the 268-ft. concrete ship.

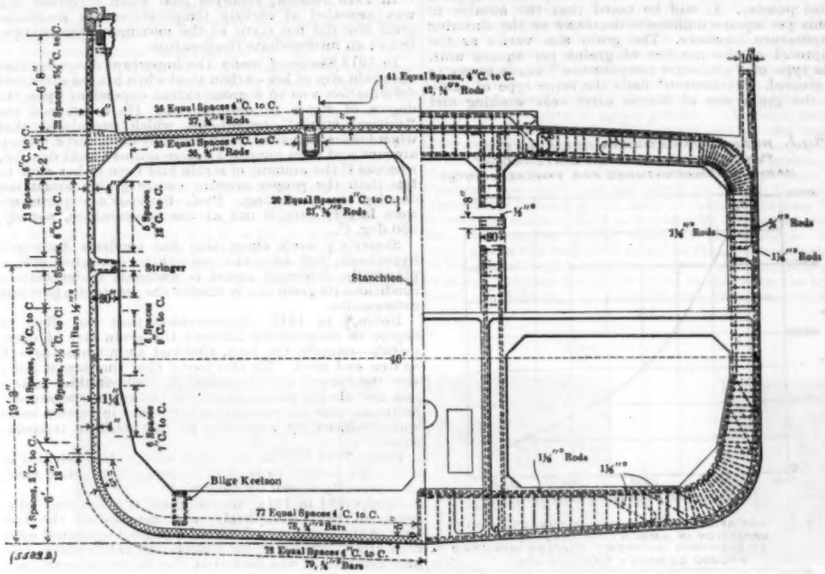

41 Equal Spaces, 4" C. to C.
42, ¾" Rods
36 Equal Spaces 4" C. to C.
37, ¾" Rods
35 Equal Spaces 4" C. to C.
36, ¾" Rods
20 Equal Spaces 4" C. to C.
21, ¾" Rods
Stringer
Stanchion
Bilge Keelson
77 Equal Spaces 4" C. to C.
78, ¾" Bars
78 Equal Spaces 4" C. to C.
79, ¾" Bars
1¼" Rods
¾" Rods

Fig. 4.—Midship Section, Showing Shell Reinforcement and Frame Details

these conditions of loading are to be met by the frames with stresses not to exceed 1,500 lb. per square inch in the steel. The results of the analysis agree with those of Dr. Bruhn published in the Transactions of the Institute of Naval Architects, 1901 and 1904. From Dr. Bruhn's analysis it is clear that the design of the concrete frame is so made that the frame is working at the above-noted safe stresses under loadings that would develop double the steel stresses in a standard steel frame of similar dimensions. In steel ships, this local action between frames would increase the stresses in the bottom plating of the ship acting as a girder from 5 tons to 10 tons, and in many cases to a much higher figure. In this concrete ship design the tensile strength in the reinforcement, due to local bending, amounts to about 3 tons per square foot, bringing the total up to slightly less than 8 tons. The bulkheads have been designed to carry a head of water on either side up to the deck. The collision bulkheads fore and aft were designed for 1,500 lb. per square inch in the concrete and 16,000 lb. per square inch in the steel. The steel stress in the engine-room bulkheads was advanced to 20,000 lb. per square inch. In the design of bulkheads for steel ships it is common practice to allow a unit stress in the steel of 22,000 lb. to 23,000 lb. per square inch. The deck is designed to carry 5 ft. of water or equivalent, which is in excess of loading on the decks of standard steel ships being built by the Emergency Fleet Corporation.

Hull Construction.—As shown by Fig. 2, page 316, the parallel middle body of the hull extends 35 per cent. of the length. There is a dead rise of 9 in. The hull is subdivided into five watertight compartments by four transverse watertight bulkheads, Fig. 2, and the bottom is strengthened by a centre keelson and two bilge keelsons, Figs. 6 and 7, while the sides of the vessel are strengthened by side stringers at about the middle depth of the hull.

The keelsons consist of concrete girders reinforced with rods in the upper and lower sections and are tied together with frequently spaced stirrups. The keelsons are worked into the transverse frames.

The frames, spaced 5 ft. apart, are also reinforced concrete girders, Fig. 8, and are continued at the main deck to form the deck beams supporting the main deck, which is made of reinforced concrete slabs 4 in. thick.

The shell of the vessel is 5 in. thick on the bottom and up to 6 ft. above the base line, while the remainder

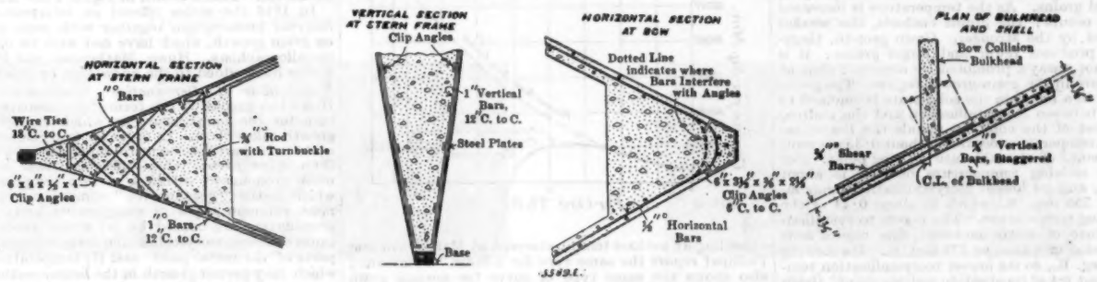

HORIZONTAL SECTION AT STERN FRAME
1" Bars
Wire Ties 18" C. to C.
¾" Rod with Turnbuckle
6" x 4 x ½ x 4" Clip Angles
1" Bars 12" C. to C.
VERTICAL SECTION AT STERN FRAME
Clip Angles
1" Vertical Bars, 12" C. to C.
Steel Plates
Base
HORIZONTAL SECTION AT BOW
Dotted Line indicates where Bars Interfere with Angles
6" x 3½" x ⅜" x 2½" Clip Angles 6' C. to C.
⅝" Horizontal Bars
PLAN OF BULKHEAD AND SHELL
Bow Collision Bulkhead
⅝" Shear Bars
¾" Vertical Bars, Staggered
C.L. of Bulkhead

Fig. 5.—Construction Details at Stem and Stern

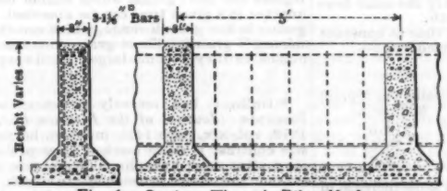


Fig. 6.—Sections Through Bilge Keelson

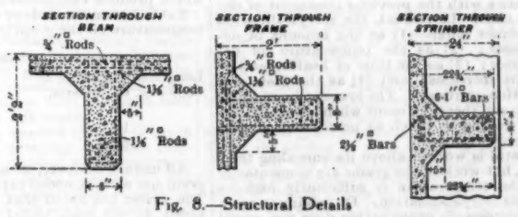


Fig. 8.—Structural Details

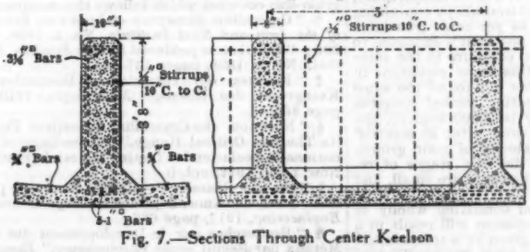


Fig. 7.—Sections Through Center Keelson

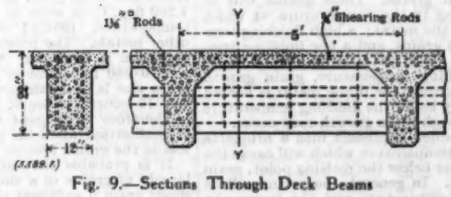


Fig. 9.—Sections Through Deck Beams

places these values between the limits of 1 ft. and 3 ft. for vessels of this type and size. The maximum righting arm occurs at 51.5 deg. and 46.5 deg. for the vessel light and fully loaded, respectively, the extreme ranges being 89 deg. and 81.5 deg. respectively. The freeboard amidships at the side is 4 ft. 9 in. While an investigation of the period of roll is a laborious operation of doubtful value and seldom attempted in the design of steel vessels, the Concrete Ship Department, nevertheless, considered it safe to say that the concentration of relatively great weight in the decks and shell in the case of the concrete vessel would aid materially in increasing the period of roll anticipated.

Good practice in steel merchant ships for a vessel of this type gives a maximum stress in the outer fibre of

Local Strength of Hull Members.—Although the transverse strength of vessels is not usually investigated with any degree of accuracy, except in the case of naval vessels, as the scantlings are taken from the books of the classification societies, nevertheless, in the case of the concrete vessel the complete transverse section was figured by the Concrete Ship Department with numerous cases of loading and heeling for every frame. The strength of the transverse frames was investigated for a large number of conditions of loading and for various immersions of the vessel. The transverse frames, Fig. 4, are designed to stand the outside water pressure—water to the gunwales—with minimum cargo load, for maximum cargo load and a sagging draught of 15 ft. 6 in. and for listed positions with loading light and heavy. All of is 4 in. thick. The shell is reinforced at the outer and inner edges with ½-in. to ¾-in. square bars parallel to the water line and spaced from 4 in. to 12 in. between centres. The horizontal reinforcing rods are located 1½ in. from the face of the concrete shell. Vertical ½-in. shear bars are also fitted between the horizontal rods extending clear around the shell and deck.

Between the hatches in the cargo holds the deck beams, Fig. 9, are supported by reinforced concrete stanchions. The foundations for the machinery consist of steel plate girders seated on extra heavy framing consisting of longitudinal reinforced girders.

As previously stated, the hull is subdivided by four transverse watertight bulkheads, two of which are the collision bulkheads and two enclosing the machinery

space. The bulkheads consist of concrete slabs reinforced with transverse and longitudinal steel and stiffened by vertical stringers and beams which are tied into the main frames and deck beams.

GRAIN GROWTH IN METALS.*†

By ZAY JEFFRIES, D.Sc., Member (Cleveland, Ohio, U.S.A.).

MOST metals met with in the industries consist of an aggregate of grains. Within each grain the atoms are arranged in a regular manner according to the system of crystallisation to which the particular metal belongs. Each grain has a different orientation from that of its neighbours; the orientation is determined by the direction of the crystallographic axes. In annealed and cast metals the grains are usually, but not always, equiaxed—that is, their dimensions in all directions are approximately equal. The external shapes of the grains are usually polyhedral; the shape of a given grain will be largely determined by the shapes of its neighbours.

Grain Growth in the Solid State.—Grain growth in metals in the solid state may occur:—

(A) On heating after cold plastic deformation. The term cold is here interpreted as meaning below the recrystallisation temperature of the particular metal.

(B) On heating a hot-worked or annealed metal to a temperature higher than it had been previously heated, or heating it for a longer time at a lower temperature.

(C) On heating compressed metal powder to relatively high temperatures, but below the melting point.

(D) On heating or cooling a metal through an allotropic point, which occurs in a temperature region of grain growth and which is accompanied by a change in crystal form.

A. When a metal is mechanically worked below its annealing temperature the grains are distorted in very much the same manner as the piece of metal taken as a whole. These grains are said to be strain-hardened. When a strain-hardened metal is heated above a certain temperature the grains undergo a marked change in structure, which gives rise to the phenomenon known as recrystallisation. The recrystallisation temperature is the lowest temperature at which the strain-hardened grains break up and form equiaxed grains. If the strain-hardened metal is heated to a temperature just above that of recrystallisation, its structure will change from one containing distorted grains to one composed of small equiaxed grains. As the temperature is increased grain growth occurs; the grains coalesce, the weaker being absorbed by the stronger. Grain growth, therefore, always produces fewer and larger grains; it is usually, but not always, promoted by extended time at any temperature in the grain-growth region. The grain-growth region in a metal in the solid state is confined to temperatures between recrystallisation and the melting point. In most of the common metals the lowest recrystallisation temperature occurs at about 0·35 per cent. to 0·45 per cent. of the absolute melting point. For example, the melting temperature of iron is about 1,700 deg. K., and its lowest recrystallisation temperature is about 750 deg. K., which is about 0·44 of the absolute melting temperature. The lowest recrystallisation temperature of strain-hardened zinc occurs near the freezing point of water, or 273 deg. K. Its melting point is 692 deg. K., so its lowest recrystallisation temperature is about 0·4 of its absolute melting point. Grain growth in most metals, therefore, in the solid state may occur with a comparatively large temperature range. The recrystallisation temperature is not a fixed temperature, but varies with the previous treatment of the metal and with time. In general, the recrystallisation temperature becomes lower—(1) as the amount of deformation increases; (2) as the temperature of deformation decreases; (3) as the time of heating at any given temperature increases; and (4) as the grain size prior to deformation decreases. The lowest recrystallisation temperature will therefore occur when a fine-grained metal has been worked as much as possible at a comparatively low temperature.

B. When a metal is worked above its annealing temperature, that is, hot-worked, the grains are momentarily distorted, but the temperature is sufficiently high to cause spontaneous recrystallisation. On cooling to room temperature a microscopic examination does not reveal distorted but equiaxed grains. These grains will be large or small, according to the temperature at which the work is finished on the metal; a high finishing temperature produces large grains, and a low finishing temperature small grains. If a metal so treated is again heated above its finishing temperature, grain growth may and usually does occur; or if the metal is heated to a temperature slightly below the finishing temperature and is exposed long enough grain growth may occur.

C. When a metal powder is pressed into a briquette and this is heated to a temperature which will cause the particles to weld together below the melting point, grain growth may take place. In general, the grains will be larger the higher the temperature and the longer the exposure at any given temperature.

D. When iron changes from the gamma condition to the non-gamma or *vice versa* at 900 deg. C., a complete change of crystallisation takes place, so that grain growth may occur when it is heated from below to above 900 deg. C., or is cooled from above to below 900 deg. C.

Normal Grain Growth in Metals.—Grain growth in metals may be divided into two classes: (*a*) normal grain growth, and (*b*) exaggerated growth. Normal grain growth occurs when a metal is composed of grains or grain fragments smaller than the equilibrium size of the grains under the given conditions, provided that the growth obeys the usual laws, namely, that the grains become larger the higher the temperature and the longer the time of exposure. Fig. 1, on this page, shows a curve representing normal grain growth with increase in temperature, but with constant time in compressed tungsten metal powder. It will be noted that the number of grains per square millimetre decreases as the sintering temperature increases. The grain size varies as the reciprocal of the number of grains per square unit. This type of "grain-size temperature" curve seems to be general. Mathewson* finds the same type of curve for the grain size of bronze after cold working and

Fig. 1. NORMAL VARIATION IN GRAIN SIZE OF TUNGSTEN INGOTS WHEN SINTERED AT VARIOUS TEMPERATURES FOR TWELVE MINUTES.

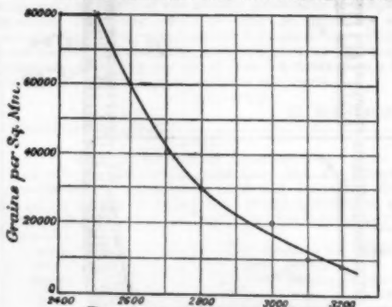
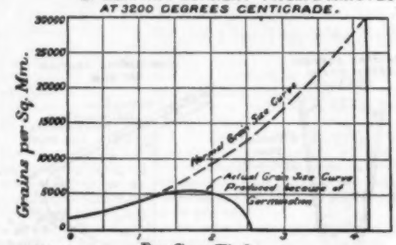


Fig. 2. VARIATION OF GRAIN SIZE OF TUNGSTEN WITH VARIATION IN AMOUNT OF ThO_2. ALL HEATED BY ELECTRIC CURRENT TWELVE MINUTES AT 3200 DEGREES CENTIGRADE.



annealing at various temperatures, and Mathewson and Phillips† report the same type for α-brass. Tammann‡ also shows the same type of curve for normal grain growth in metals.

It will be shown later that what is termed normal grain growth is brought about by exactly the same laws which produce exaggerated grain growth.

Table I is an example of the effect of time at constant temperature on the grain growth of Armco iron:—

TABLE I

Length of Exposure at 850 deg. C. Hours.	Grains per Square Millimetre
1	318·0
10	70·0
168	2·5

All metals, however, do not show this same increase in grain size with extended exposure at a given temperature. The writer has found that nickel-iron alloys containing about 44 per cent. nickel and 56 per cent. iron have about the same grain size after one hour's exposure to 1,200 deg. C. as after 30 seconds' exposure to the same temperature. Beilby§ reports this same condition in other metals. The present author has found the same condition in tungsten. On reheating worked tungsten rods 0·080 in. diameter quickly to 3,000 deg. C., the grain size is approximately the same after 30 seconds' and 10 hours' exposure. The velocity of grain growth is therefore very great during the first stages of recrystallisation when the grain fragments are small, and less as the grains become larger.

It is probable that any metal consisting wholly or largely of grains of a single component will result in a single grain if sufficient time be given at a temperature slightly below that of melting. After recrystallisation the grain-size contrast is usually slight and growth is consequently slow; grain-size contrast at first increases as growth proceeds, but a maximum is reached after which a decrease is noted.* This slow process of grain growth is analogous to germinative growth, with the exception that germination produces large grains quickly.

Exaggerated or Abnormal Grain Growth.—In 1898 Stead† published two papers dealing largely with grain growth in steel. He reported, among other things, the abnormal grain growth in low carbon steel in the temperature region below 900 deg. C.

In 1910 Joisten‡ reported that when deformed iron was annealed at various temperatures its maximum grain size did not occur at the maximum temperature, but at an intermediate temperature.

In 1912 Sauveur§ made the important discovery that the grain size of low-carbon steel when heated after cold deformation was to a great extent dependent upon the degree of strain or deformation. He announced the "critical strain" hypothesis, which postulated that when low-carbon steel was plastically deformed a certain amount and then annealed coarse grains would develop, whereas if the amount of strain had been either more or less than the proper amount coarse grains would not develop on annealing. Prof. Sauveur's experiments were largely carried out at one temperature, namely, 650 deg. C.

Sherry's‖ work along this line confirms Sauveur's hypothesis, and adds the generality that when cold a plastically deformed metal is annealed under certain conditions its grain size is smaller the greater its previous deformation.

Robin,¶ in 1913, demonstrated that the effect of degree of deformation affected the grain size of other metals—namely, tin, lead, zinc and aluminium—as well as iron and steel. He also found that the largest grain size resulting from annealing the cold-worked metals was not always produced at the highest temperatures; he found that the maximum grain size in certain cases was produced by annealing at intermediate temperatures.

Ruder,** in 1913, showed that silicon steel behaved in a manner similar to that of ordinary low-carbon steel, as previously shown by Sauveur.

Chappell,†† in 1914, investigated the Sauveur phenomenon more completely, and established the fact that in the overstrained portions of steel coarsened after critically straining, grain growth had taken place. He also established the fact that the region of maximum grain growth occurred at higher temperatures the less the strain. This is shown in Fig. 8, Plate XXVII.

In 1916 the writer offered an interpretation of the Sauveur phenomenon together with some general laws on grain growth, which have met with no opposition by metallographists. Howe, Mathewson and Phillips, and Ruder have added to the knowledge on this subject.‡‡

Definition of Germinative Temperature.—Professor Howe has suggested the term "germinative" temperature for the temperature at which exaggerated grain growth takes place. In order for exaggerated growth to occur some parts of the metal must permit growth faster than other parts. This differential rate of growth is most pronounced within a certain temperature range, which is the "germinative" temperature range. The most common types of exaggerated grain growth by germination are caused by (*a*) strain gradients, which cause different recrystallisation temperatures in different parts of the metal piece and (*b*) temperature gradients which may permit growth in the hotter sections (growth range), and not permit growth in the colder portions (inert range). At the boundary between the growth and inert regions the inert grains which cannot coalesce with one another in a given time can be absorbed by the adjacent grains in the growth range, which are then called "germinant" grains. These grains increase their power of attack as they become larger, until they are eventually

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* Part I of thesis for degree of Doctor of Science, Harvard University, Cambridge, Mass., submitted May 1, 1918.

† Paper read before the Institute of Metals, September 11, 1918.

* "A Metallographic Description of some Ancient Peruvian Bronzes from Machu Picchu," *American Journal of Science*, 1915, vol. xl, page 549.

† "Recrystallisation of Cold-Worked Alpha Brass on Annealing," Transactions of the American Institute of Mining Engineers, vol. iv, pages 608–670.

‡ *Lehrbuch der Metallographie*, 1914, page 79.

§ "The Hard and Soft States in Metals," *Journal of the Institute of Metals*, No. 2, 1911, vol. vi, pages 5–43.

* Gulliver has recently presented a paper to this Institute (*Journal of the Institute of Metals*, No. 1, 1918, vol. xix, page 145), in which he states that grain-size contrast is more marked after prolonged annealing than after short annealing. I am sure that he did not extend the time sufficiently to reach the maximum grain-size contrast, and hence he did not note the lesser grain-size contrast which follows the maximum.

† "Crystalline Structure of Iron and Steel," *Journal of the Iron and Steel Institute*, No. 1, 1898, pages 145–205; "Brittleness produced in Soft Steel by Annealing," *ibid.*, No. 2, 1898, pages 137–184.

‡ "Einfluss der thermischen Behandlung auf die Korngrosse des Eisens," *Metallurgie*, 1910, vol. vii, page 456.

§ "Note on the Crystalline Growth of Ferrite below its Thermal Critical Range," Proceedings of the International Association for Testing Materials, Sixth Congress, New York, 1912, vol. ii.

‖ "On the Coarsely Crystalline Structure produced in Mild Steel on Annealing," *Metallurgical and Chemical Engineering*, 1912, page 666.

¶ "Recherches sur le Developpment des Grains des Métaux par Recuit après Ecrouissage," *Revue de Métallurgie*, 1913, vol. x, pages 722–757; "Developpment des Grains de Recuit dans les Alliages," *Revue de Métallurgie*, 1913, vol. x, pages 758–768.

** "Grain Growth of Silicon Steel," American Institute of Mining Engineers, 1913, vol. xlvii, pages 569–583.

†† "Recrystallisation of Deformed Iron," Journal of the Iron and Steel Institute, No. I, 1914, pages 460–498.

‡‡ Mathewson and Phillips, Transactions of American Institute of Mining Engineers, vol. liv, page 608. Jeffries, *idem*, page 658. Howe, *ibid.*, vol. lvi, pages 551–570. Jeffries, *ibid.*, pages 571–581. Howe, *idem*, pages 582–588. Discussion of the three preceding papers by Ruder, Carter, Richards, Boylston, Mathews and Jeffries, pages 589–599.

able to absorb some or all of the hotter grains in the growth range.

General Laws of Grain Growth.—Grain growth, both normal and exaggerated, depends largely on the following general laws:

1. The attacking power of a grain increases directly with its size. A large grain has greater power of attack or greater absorptive power than a small one. Conversely, a small grain has both slight power of attack and slight power of resistance to absorption. Grain-size contrast will therefore favour grain growth.

2. The velocity of grain growth increases as the temperature increases. There is no grain growth below the recrystallisation temperature of the metal. The velocity of growth in the solid state progressively increases as the temperature increases, and is greatest just below the melting point of the metal.

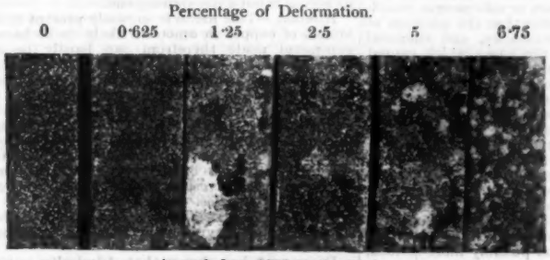
3. A grain which has been deformed below its recrystallisation temperature no longer acts as a unit as regards grain growth, but acts as if it had been disintegrated into fragments smaller than the initial grain, and these become still smaller as the degree of deformation increases, as the temperature of deformation decreases, and as the grain size prior to deformation decreases.

4. Two small adjacent grains or adjacent fragments of a deformed grain may not in a given time and at a given temperature be able to coalesce to form one larger grain, but may both be absorbed at the same temperature and in the same time by an adjacent grain larger than themselves.

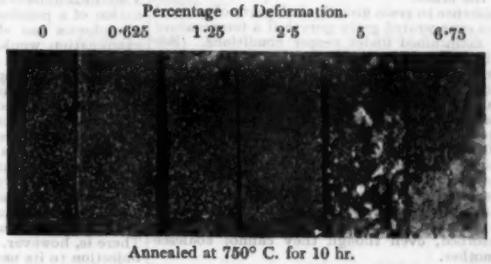
the surface to the axis of the bar. This bar was heated to 650 deg. C. for seven hours. The recrystallisation temperatures of the more severely strained portions near the surface were below 650 deg. C. At an intermediate portion at which large grains developed the recrystallisation temperature was 650 deg. C. At the boundary between the recrystallised and the unrecrystallised portions large grains developed, because the power of attack of the recrystallised grains was greater than the power of resistance of the adjacent grain fragments in the unrecrystallised portion. The unrecrystallised portion abutting the recrystallised portion may be called the inert range, and the grain fragments which compose it are themselves inert, so far as coalescence with each other is concerned, below their own recrystallisation temperature. They are, however, not immune from attack by larger and more perfectly developed grains which have formed in a region of grain growth. The local strain gradients determine the final grain size of the metal after annealing. The less the total strain the larger will be the grain size after annealing. The large grains developed, therefore, at the germinative temperature in Professor Sauveur's bent bar would feed upon the unrecrystallised or inert grains near the axis of the bar, but toward the surface there is a gradually decreasing grain size, the smallest grains being at the surface. The larger grains will feed more easily on the inert region than on the growth region when the temperature is maintained constant, because the grains of the former have the least power of defence. If a metal has been so severely

to a point which will permit growth simultaneously in all parts of the briquette a fine-grained structure results, even though the temperature gradient may have been greater than in the previous example. When a metal has been severely cold worked so that recrystallisation occurs in all parts at about the same temperature, exaggerated grain-growth conditions can be produced by a temperature gradient which maintains one portion above the recrystallisation temperature and another portion below it. The history of growth in this case is the same as that given above for the compressed metal powder. When a metal changes from one allotrope to another in a temperature region permitting grain growth and at the same time changes its crystal form, the grain size of the new allotrope may be controlled to a large extent by the temperature gradient obtaining at the time of the transformation. If the temperature gradient is such that one portion of the metal is maintained in the temperature region of one allotrope and another portion in the temperature region of the other allotrope, a condition of exaggerated or abnormal grain growth may occur. (See Fig. 41, to be published later.)

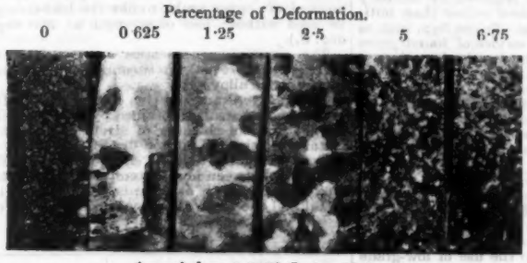
8. The higher the germinative temperature the quicker will large grains develop, and the grains will usually be larger the higher the germinative temperature. If, for example, the germinative temperature is increased by adding non-metallic obstructions to grain growth, like thoria to tungsten, the coarse-grained structure developed at the germinative temperature will form in less time and with larger grains than at a lower ger-



Annealed at 950° C. for 10 hr.



Annealed at 750° C. for 10 hr.



Annealed at 1,100° C. for 10 hr.

Annealed at 800° C. for 10 hr.

SILICON STEEL STRIPS STRAINED VARIOUS DEGREES COLD AND THEN HEATED AS NOTED ABOVE; FULL-SIZED. (RUDER.)

5. Any process of deforming metals below their recrystallisation temperatures produces different degrees of strain in different parts of the metal. These differences in degree of strain may be called strain gradients. If a metal, for example, is placed on an anvil and hit with a hammer, it is deformed more in the regions near the anvil and near the hammer than in interior portions. If a metal is rolled it receives more deformation at the surfaces in contact with the rolls than in the interior. If a metal is deformed by stretching, as in the jaws of a tensile testing machine, certain interior grains may be deformed as much as certain surface grains, but there will be strain gradients produced, due to the directional properties of the grains. The grains composing the metal will be oriented in different directions, so when a tensile load is applied the first deformation will occur in those grains oriented in such a manner that the direction of load is parallel to their direction of least resistance to deformation. As the stretching progresses the grains oriented in more unfavourable positions will be forced to deform, but the degree of deformation of these at any given stage of the stretching will be less than that of the first grains to undergo deformation. This will produce numerous strain gradients throughout the piece of metal. The strain gradients are most marked in the initial stages of the deformation, and tend to disappear as the metal becomes more severely deformed. In the true sense the strain gradients due to any kind of deformation never disappear; but the centres or points of equal strain become so close together that their number in a given volume is equal to or greater than the number of grains in the same volume of equilibrium at the annealing temperature, and hence coarsening by germination is defeated unless a temperature gradient obtains or the metal is non-homogeneous.

6. A strain gradient in the metal produces a recrystallisation gradient, and this under proper temperature conditions will produce exaggerated grain growth, according to the germinative hypothesis. In Sauveur's bent bar, for example (Fig. 4, Plate XXVII), the axis of the bar was not strained at all, and the surface of the bar received maximum train. A strain gradient occurred from

strained by cold work that the recrystallisation temperature of all parts occurs at approximately the same temperature, then it will not be possible by ordinary muffle heating to develop large grains at the recrystallisation temperature. Grain growth or germination will take place from many centres simultaneously, and each germinant centre or grain will find no inert grains to feed upon, so normal grain growth will result.

7. If a metal undergoes any marked change in grain size at a certain temperature, or within a certain temperature range, a temperature gradient which maintains one part of the metal above this certain temperature and other parts below may produce coarse-grained structures. A temperature gradient itself is not always sufficient to produce exaggerated grain growth, but the temperature of the metal must be within certain limits. When metal powder, for example, is pressed into a briquette and sintered below its melting point, there will be a temperature region on heating within which rapid coalescence of the particles will take place. If the heating is effected by electric current the inner portion of the briquette will be hotter than the surface, that is, a temperature gradient will obtain. If a temperature is maintained in the inner portions of the briquette which will permit rapid coalescence of the particles while the surface of the briquette is at a temperature too low for rapid coalescence, large grains will develop at the boundary between the growth and inert regions. These large grains will extend their boundaries into the inert range, and may grow to the surface of the briquette. In the growth range grain growth is retarded because the individual grains have begun growth simultaneously, and after absorbing the inert and weak grains are approximately the same size, and consequently have no more inert grains to feed upon. They are about the same size, because they have been produced under substantially the same conditions. After the germinant grains have reached a size considerably larger than the grains in the hotter or growth region the latter are absorbed, so that the first germinant grains finally conquer all of the other grains in the briquette. (See Figs. 9 to 18, Plate XXVII.) On the other hand, if the temperature is raised quickly

minative temperature. (Compare Figs. 19 to 27 with Figs. 9 to 18 on Plates XXVII and XXVIII.)

The same is true of germinative temperatures produced by deformation. The less the deformation the higher will be the germinative temperature, and the larger will be the grains developed at the germinative temperature. (See engravings above.)

9. Initially fine grains or small grain fragments favour exaggerated grain growth at the germinative temperature. This rule applies in so far as it is not opposed to section 8. If the fine-grained fragments are the cause of lowering the germinative temperature, then the development of coarse grains at the germinative temperature may be defeated. If the grains or grain fragments, however, at the germinative temperature are much smaller than the equilibrium grains at that temperature, the formation of coarse-grained structures will be facilitated.

10. The rate of heating a metal through the germinative temperature range will determine to a large extent the resulting grain size. If, for example, Professor Sauveur had heated his critically stretched specimen (Fig. 4) quickly to a temperature to near 800 deg. C., the result would have been a comparatively fine-grained structure in place of the coarse-grained one which he obtained at 650 deg. C. On the other hand, had he heated the under-strained bar (Fig. 5) to a temperature above 650 deg. C., the result would have been a coarse-grained structure than he obtained in his critically strained bar at 650 deg. C.

In severely cold-worked metals heated by electric current if the germinative temperature is maintained for a considerable time, and at the same time a temperature gradient exists in the piece of metal, coarse grains may develop, but if the temperature is raised quickly above that of germination a fine-grained structure will be produced. (See Figs. 34 to 39.) The same is true of compressed metal powders. If they are heated above the germinative temperature quickly a fine-grained structure is produced, while if the germinative temperature is maintained a long time coarse-grained structures are produced. (See Figs. 19 to 27.)

11. The time required for recrystallisation is less the

higher the temperature. If a metal has been cold worked a certain amount it may have just time completely to recrystallise in ten seconds at a certain high temperature. The same metal may recrystallise in ten minutes at a certain lower temperature, and in ten hours at a still lower temperature, &c. A metal which will not recrystallise in a few hours at a certain temperature may recrystallise in a longer time at that temperature. Some of the metals which we say recrystallise at a temperature of 200 deg. C. may actually recrystallise at room temperature in the course of hundreds of thousands of years.

Time, therefore, is an important factor in germination or in grain growth, because the inert grains are only inert for certain time periods. Grain growth becomes a race between the germinant grains and the inert grains. If the latter can increase their size by coalescence with one another before the germinant grains can absorb them, they may have won the race. Exaggerated grain growth will be most pronounced under conditions in which the germinant grains have the greatest excess of growth velocity above that of the grains which they feed upon. The germinative temperature may be raised by shortening the time of heating.

12. The temperature range within which a sudden increase in the velocity of grain growth takes place on heating can be raised by foreign substances which act as mechanical obstructions to coalescence. In alloys composed of more than one constituent the particles of each constituent interfere with the coalescence of the particles of the other.

Equal resistance to grain growth of all parts of a metal may produce exaggerated grain growth if a temperature gradient is maintained under proper conditions. (See Figs. 19 to 23, Plate XXVII.)

Unequal resistance to grain growth may cause exaggerated growth at a constant temperature. A good example of this is found in low-carbon steel, the surface of which has been partially decarbonised by oxidisation. When a piece of steel of this nature is heated to a temperature between 700 deg. and 800 deg. C., either with or without previous cold deformation, grain growth is more rapid in the low-carbon than in the high-carbon regions because of the obstruction of the pearlite in the latter. After the grains in the low-carbon region become considerably larger than those in the high-carbon region the latter may be absorbed, even though they cannot coalesce with one another.

(To be continued.)

ADMIRALTY GUN-METAL.

*The Influence of Impurities on the Mechanical Properties of Admiralty Gun-metal.**

By F. JOHNSON, M.Sc., Member (Birmingham).

THE literature of the subject contains little information concerning the ascertained results of adding other metals to Admiralty gun-metal. The influence of lead has received most attention. So far as the author has searched, no attempt appears to have been made to make up alloys of Admiralty gun-metal composition from pure metals under standardised conditions, and to ascertain the alteration in mechanical properties which may be brought about by the addition of other metals. This is what the author, under adverse conditions as regards time, material, and assistance, has attempted to do. Before proceeding to a description of the few experiments which it has been possible to carry out, it will be advisable to review briefly the views and experimental results of other workers.

This will be effected most clearly perhaps by taking the added elements seriatim. The choice of Admiralty gun-metal as the basis alloy may appear to some as requiring justification. The justification which the author offers is that this particular alloy finds greater favour amongst engineers than any other alloy, composed mainly of copper and tin, if the extensive and highly important series of phosphor bronzes be excepted. The popularity of this alloy is based on no misconception. It is undoubtedly superior to its progenitor, zinc-free gun-metal.

As a casting alloy it possesses few equals among the copper-rich alloys, whilst its range of mechanical properties may be enormously extended by heat treatment. Unannealed castings are used for journal bearings, water and steam fittings, &c., whilst annealed castings are probably better for fittings of pumps used for pumping mine-waters and other corrosive liquids.

Unannealed castings have a metastable structure, the tin-rich eutectoid being present only on account of the relatively rapid rate of cooling. Thus one of the necessary conditions of a bearing-metal are fulfilled, viz., a uniformly-distributed phase (delta) of great hardness possessing a low co-efficient of friction in a relatively soft matrix (alpha phase) possessing good thermal conductivity.

Annealing, if sufficiently thorough, establishes equilibrium, the eutectoid reverting to the homogeneous beta phase, this in turn passing into solution in the alpha phase.

Thus an alloy consisting entirely of homogeneous alpha may be produced by annealing, and this should be more resistant to corrosion than the metastable alpha + eutectoid structure in the unannealed casting. There appears to be no experimental evidence on this point, but it seems reasonable to assume that the obliteration of an electro-negative constituent by annealing should serve to reduce corrodibility.

The work of H. S. and J. S. G. Primrose† on the annealing of Admiralty gun-metal affords striking evidence of the improvement in mechanical properties of this alloy affected by heat treatment.

The conditions recommended are—temperature, 700 deg. C.; time, 30 minutes.

Taking the added elements seriatim, therefore, the following is a précis of the views held by previous investigators.

Aluminium.—H. S. Primrose* states that aluminium is never found in gun-metal unless purposely added. Its ill-effects are comprised in the formation of a skin (alumina) on the skimmed surface of the molten metal, difficult to remove, in the increase in contraction and in increased corrodibility. By contraction, Primrose doubtless means the cavities formed by shrinkage of the metal during solidification. These cavities or "draws" may be obviated by efficient feeding by means of adequate runners and risers. Guillet† has shown that a small addition of aluminium (leaving only a trace in the casting) enhances the mechanical properties of gun-metal of Admiralty type (see Table IV).

Dewrance‡ objects to aluminium on account of the excessive shrinkage produced.

The author would point out that this increase of shrinkage must be regarded, if unaccompanied by disadvantageous structural changes, as the hall-mark of strength and soundness. One has not to seek far for an analogous case. The addition of phosphorus to tough-pitch copper results in the formation of a depression at the surface of an ingot or wire-bar which would otherwise be level. Visual examination of the fracture or microscopic examination of a polished surface proves that the addition of phosphorus has eliminated gas-cavities, and chemical examination would show that the gases which caused those cavities had also been eliminated. Thus the condition which is opposing the natural property of the metal to become more dense, and, therefore, to occupy a smaller space when solid than when molten, is removed.

Physical and mechanical tests will show that the phosphorised copper is denser, stronger and tougher.

Similar beneficial results accrue from the addition of aluminium to Admiralty gun-metal *in very small proportion*. The author would, therefore, plead for a reconsideration of the use of aluminium, believing that foundrymen could produce improved castings by observing the recommendation made by Primrose to feed efficiently. There is, however, the other, and possibly more serious, objection to its use, viz., the formation of the tenacious film of alumina which cannot be removed by ordinary skimming. This trouble is increased rather than mitigated by remelting. Possibly, some efficient flux, such as cryolite, may be pressed into the service of foundrymen in order to obviate this very serious drawback to the use of aluminium. The author has greater faith in the employment of some such specific as aluminium or phosphorus for the elimination of unsoundness than in merely controlling temperature, whilst not losing sight of the fact that control of temperature, either by pyrometer or by expert judgment, cannot fail to contribute towards the same end.

Antimony.—L. Parry§ refers to the common practice of adding antimony to bronze, but has no experimental evidence to offer in illustration of its effects.

H. S. Primrose‖ refers to its harmful effects, but indicates that its presence in gun-metal in harmful proportion can be attributed only to the use of low-grade tin. If, however, as much as 0·1 per cent. be present, castings, with the exception of very large ones which have been slowly cooled, will not be embrittled.

H. S. Gulick¶ attributes to antimony increase in hardness, closeness of grain, and tensile strength, with lowering of percentage elongation and conductivity, when added to copper-tin alloys.

Arsenic.—The only figures which the author has been able to trace in connection with the influence of arsenic on Admiralty gun-metal are those given by R. T. Rolfe** as follows:—

TABLE I.

Arsenic per Cent.	Average Number of Tests.	Yield-Point. Tons per Sq. In.	Tensile Stress. Tons per Sq. In.	Elongation per Cent.
Trace	114	11·2	16·6	14·3
0·30	172	10·7	15·5	12·4
0·75	10	11·2	14·4	7·4

These figures indicate that arsenic has a detrimental influence, but that up to 0·3 per cent. the influence is not at all serious. The drawback to this series of tests is the absence of complete analytical data. The influence attributed to arsenic alone may be shared by other impurities.

H. S. Primrose†† regards arsenic as "one of the fruitful sources of failure in the kinds of gun-metal made from scrap or poor grades of copper ingots." He holds that the action of arsenic in copper is a deoxidizing one, but the author has shown that this is not the case‡‡. Primrose further argues that, "with larger amounts," arsenic forms a very brittle eutectic, which is "comparatively stable, and, although some of the arsenic must be volatilised when the copper is melted in making gun-metal, there is sufficient left to cause an excessive separation of the bronze eutectoid, and thus yield a very poor gun-metal."

Without a clearer definition of "larger amounts," it is difficult to discuss this statement. However, if we take 0·84 per cent. arsenic as the limit, being the largest amount to which Primrose refers, we are still short of the amount required to produce the alpha + beta eutectic. It would seem, however, a correct interpretation of the action of arsenic to ascribe to it the throwing out of tin from solution in the alpha phase, thus creating more eutectoid, and hence greater brittleness. But caution is necessary here, because an increase in the quantity of eutectoid does not necessarily mean greater brittleness. It is the physical condition of the eutectoid which is of greater importance than a slight increase in its amount.

The author is not disposed to quarrel with the introduction of arsenic into Admiralty gun-metal. More important, very often, than slight lowering of tensile strength and elongation is an increase in soundness. That arsenic can act beneficially on copper from the point of view of reducing porosity, the author has proved in works practice over and over again. That it can act similarly in Admiralty gun-metal is not a rash assumption to make. E. Lewis claimed that the addition of arsenic to gun-metal was not only not detrimental but desirable. It must, however, be clearly understood that its action is not a deoxidising one.

Bismuth.—This metal is so rarely present in reputable brands of copper in amounts likely to be harmful that gun-metal made therefrom can hardly be adversely affected even in a minute degree. Primrose states that it may be found in scrap material, and that if the amount found in gun-metal should even approach 0·1 per cent. the castings would be worthless. Although bismuth exerts its most deleterious effect on hot-working properties, its effect on the mechanical properties of gun-metal at normal temperatures would be detrimental, as it separates out as a brittle intercrystalline constituent, thus lowering the resistance of the alloy to both static and dynamic stresses.

Lead.—More investigations have been made on the influence of lead in gun-metal than on the influence of any other metal.

Dewrance* has shown that Admiralty gun-metal in which 0·5 per cent. lead had displaced an equivalent amount of copper could, unlike the lead-free gun-metal, be used without loss of strength at 550 deg. F. (286 deg. C.).

The machining properties are, as is well known, materially improved, the turnings being shorter than in the lead-free alloy.

Sir Henry Oram, in the discussion on Dewrance's paper, quoted results (obtained by the Admiralty) which do not confirm the loss of strength of lead-free gun-metal when heated to 450 deg. F. (232 deg. C.). The figures given in Table II show that the difference in properties between normal temperature, and 450 deg. F. (232 deg. C.), both as regards ordinary 88 : 10 : 2 gun-metal and the same alloy containing 0·5 per cent. lead, is only quite small.

TABLE II.

Temp. of Test.		Admiralty Gun-metal. Copper 88, Tin 10, Zinc 2 per Cent.		Gun-metal with Lead. Copper 87½, Tin 10, Zinc 2, Lead ½ per Cent.		Authority.
Deg. F.	Deg. C.	Ultimate Tensile Stress. Tons per Sq. In.	Elongation per Cent.	Ultimate Tensile Stress. Tons per Sq. In.	Elongation per Cent.	
60	15	16·4	11·0	16·5	8·0	Dewrance
400	205	9·5	1·0	—	—	
500	260	9·8	1 8	16·0	13·2	
550	288	—	—	15·8	18·0	
600	316	9·15	1·8	11·3	8·0	
700	371	7·0	0·25	8·25	2·0	
60	15	14·5	14·0	15·1	18·5	Admiralty
450	232	13·6	13·9	14·8	20·3	Admiralty
450	232	9·7	1·4	16·2	12·2	Dewrance†

† Obtained by interpolation from curve. (See original paper.)

Dewrance's bars were cast nearly to size in green sand.

The chief comment which the author desires to make in connection with these tests is that, owing to the extreme sensitiveness of this alloy to changes of casting conditions, none of these results can be accepted as final. It would have been advantageous to have taken the tests in pairs, each pair from a single cast bar, the one test at normal temperature and the other at the desired high temperature.

In Table III are given the results obtained by H. S. Primrose from adding lead to gun-metal. In each case the lead displaces its equivalent weight of copper. Gun-metal of Admiralty type containing lead is often used as a bearing metal. The presence of lead lowers the rate of wear, but increases the friction co-efficient.

Primrose states that the bearing is not so reliable when the lead is in large particles and irregularly distributed as when it is in small, well-distributed particles. He states that when lead is added to a zinc-free bronze, a tin-lead eutectic separates out, but he offers no evidence in support of this claim.

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* Paper read before the Institute of Metals, Wednesday, September 11, 1918.

† *Journal of the Institute of Metals*, No. 1, 1913, vol. ix, page 158.

* *Metal Industry*, vol. xii, page 437.

† *Etude Industrielle des Alliages Métalliques.*

‡ *Journal of the Institute of Metals*, No. 1, 1914, vol. xi, page 214.

§ L. Parry, "Notes on Alloys."

‖ *Loc. cit.*

¶ *Foundry*, vol. xlv, page 68.

** Proceedings of the British Foundrymen's Association, 1914–15, page 88.

†† *Metal Industry*, vol. xii, page 437.

‡‡ *Journal of the Institute of Metals*, No. 2, 1910, vol. iv.

* *Journal of the Institute of Metals*, No. 1, 1914, vol. xi, page 214.

TABLE III.

Mark.	Lead per Cent.	Tensile Stress. Tons per Sq. In.	Elongation per Cent.	Brinell Hardness.	Melting-Point. Deg. C.
—	—	18·6	18·4	70	998
A	0·5	17·4	16·8	65	965
B	1·5	15·3	17·1	60	920
C	3·0	14·9	12·5	55	870

Iron.—None of the above-mentioned investigators have a good word to say for the presence of iron in Admiralty gun-metal. Dewrance and Philip state that a hard iron-tin constituent is formed. Primrose confirms this, and states that this constituent makes its appearance "in the delta constituent" with as little as 0·11 per cent. to 0·15 per cent. The effect of this constituent is not determinable until the iron has reached 0·3 per cent., whilst the effects of 0·6 per cent. to 1 per cent. are very harmful. Gulick states that iron raises the tensile strength and lowers the elongation.

Manganese.—Gulick states that manganese acts as a deoxidiser and increases the soundness, tensile strength, and toughness of bronze castings, whilst reducing the elongation only slightly.

Nickel.—Little is known about the influence of nickel. Dewrance does not favour its addition owing to its alleged action of liberating occluded gas during cooling of the casting, thus causing porosity.

G. A. Boeddicker, in the discussion on Dewrance's paper, rightly points out that if added as cupro-nickel (50–50) it does not require so high a temperature for its liquefaction, thus obviating the risk of overheating the bronze.

Gulick attributes to nickel a beneficial influence in aiding to form a dense, close-grained structure, and in lowering the rate of wear.

Silicon.—The employment of silicon as a deoxidising agent in preference to phosphorus for bronze required to be used for electrical purposes is old. In Table IV it will be seen that, according to Guillet, a small amount of silicon as a deoxidiser does not improve the mechanical properties of zinc-bronze.

J. S. G. Primrose, in the discussion on Dewrance's paper, objects to the presence of even a small proportion of silicon, owing to its hardening effect both at normal and at high temperatures. He considers that silicon can be taken up by gun-metal which has been melted under a flux of glass.

TABLE IV.—(*Guillet's Experiments.*)

Composition.				Added Impurity.	Condition.	Ultimate Tensile Stress. Tons per Sq. In.	Elongation per Cent.
Copper per Cent.	Tin per Cent.	Zinc per Cent.	Lead per Cent.				
89·0	9·0	1·5	0·5	nil	cast	18·0	24
89·0	9·0	1·5	0·5	trace P	cast	20·0	41
89·0	9·0	1·5	0·5	0·13 P	cast	18·0	19
89·0	9·0	1·5	0·5	trace Si	cast	17·2	20
89·0	9·0	1·5	0·5	trace Al	cast	19·4	43
90·0	10·0	—	—	trace P	rolled and annealed	25·0	67

Zinc.—As the author is dealing with the influence of minute quantities of elements on an alloy containing 2 per cent. of zinc, this metal need not be considered. It is well known that beyond 2 per cent. no advantage is to be gained, and, in fact, further additions of zinc result in deterioration. He would, however, refer briefly to the work of Guillet and Révillon,* who endeavoured to work out the "co-efficient of equivalence" of zinc when added to bronze. In a given sample of bronze, in which zinc has been introduced at the expense of tin, the zinc may be determined by chemical analysis, giving the real figure. But by microscopic examination it is found that the amount of α present is *more* than is found in a zinc-free bronze of similar tin content. In view of the author's experience and of the work of L. Hoyt,† these statements are difficult of acceptance.

If Hoyt's ternary diagram be studied, it will be found that, maintaining the proportion of copper constant, so soon as the composition of the alloy is changed by substituting zinc for tin, the ternary alpha + eutectoid phase field is being traversed towards the ternary alpha phase field, and when sufficient zinc has been substituted for tin, the alpha + eutectoid field is left behind, and the alloy consists entirely of alpha. This may readily be followed from a glance at Fig. 1. Any point on AB represents an alloy of the same copper content, say 88 per cent. At the point B the alloy is 88 per cent. copper, 12 per cent. tin, and the constitution is alpha + eutectoid. Travelling along the line towards A, the eutectoid *diminishes* in quantity, and with an alloy consisting of, say, 88 per cent. copper, 6 per cent. zinc, and 6 per cent. tin, the constitution is all alpha. (Point X.)

The findings of Guillet and Révillon are, therefore, incompatible with the constitutional diagram, and their formula is apparently based on a misconception. The formula is as follows:—

$$Cf = 1 + \frac{(A - A')\,100}{qA'}$$

in which A = actual percentage of copper.
A' = fictitious percentage of copper.
q = amount of zinc found by analysis.

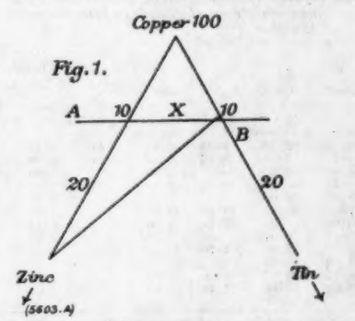
* *Revue de Metallurgie*, 1910, vol. vii, page 429.
† *Journal of the Institute of Metals*, No. 2, 1913, p. 235.

TABLE V.—SERIES I.

Analysis.				Alloys as Cast (Chill).				
Mark.	Copper per Cent.	Tin per Cent.	Impurity per Cent.	Yield-Point. Tons per Sq. In.	Ultimate Tensile Stress. Tons per Sq. In.	Elongation per Cent. $C = 4\sqrt{\text{area}}$.	Brinell Hardness.	Remarks.
S	88·0	9·85	nil	11·7	23·15	19·0	—	Metal fluid.
A	87·09	10·08	0·94 As	11·22	25 0	32·4	89	Surface-skin on molten metal.
B	87·0	10·0	1·0 Al	12·75	22·65	9·55	95	Metal fluid and very smooth surface on casting.
B1	86·97	9·85	1·01 Al	13·55	22·9	9·55	100	
C	87·0	10·0	1·02 Sb	11·12	23·15	28·5	80	Metal fluid.
D	87·3	10 0	1·0 ferro-silicon	11·4	23·9	21·9	96	Metal a little viscous.
E	87·06	10·0	1·05 Ni	12·25	25·02	24·8	82	Metal fluid. Nickel added as 50–50 cupro-nickel.
F	87·28	10·05	0·67 Si	17·15	24·3	4·75	117	Very fluid metal.
G	87·18	9·99	1·02 Mn	14·1	22·9	14·3	89	Metal viscous.
H	86·72	10·4	0·35 Fe	16·8	27·1	21·0	96	Iron added as ferro-copper.
H1	88·7	10·08	0·65 Fe 0·23 Al	16·3	27·8	18·1	—	Metal pours sluggishly. Castings scabby. Metal fluid.
I	87·0	10·0	1·0 boron-copper	12·15	23·	18·1	80	
J	86·98	10·8	1·0 Pb	12·25	22·1	21·9	80	Metal fluid.

TABLE VI.—SERIES II.

Composition.				Alloys as Cast.				Alloys Annealed.			
Mark.	Copper per Cent.	Tin per Cent.	Impurity per Cent.	Yield-Point. Tons per Sq. In.	Tensile Stress. Tons per Sq. In.	Elongation per Cent.	Brinell Hardness.	Yield-Point. Tons per Sq. In.	Tensile Stress. Tons per Sq. In.	Elongation per Cent.	Brinell Hardness.
SR	88 0	10·0	nil	15·4	23·3	10·0	89	10·05	25·6	66	—
AR	87·0	10·0	0·9 As	15·8	23·4	5·5	100	10·18	26·05	69	74
B1	86·97	9·85	1·01 Al	—	—	—	100	10·68	26·05	47	74
CR	86·97	9·97	0·8 Sb	15·6	20·95	5·5	96	9·57	24·7	52	65
ER	86·86	9·87	1·15 Ni	14·0	23·75	13·0 Broke on Gauge mark	98	9·72	25·65	78	74
FR	87·2	10·2	0·7 Si	16·05	24·25	6·5	109	11·9	28·0	68	77
H1	88·7	10·08	0·65 Fe 0·23 Al	—	—	—	100	14·85	29·3	55	—
JR	86·88	10·08	1·06 Pb	12·83	21·9	12·0	86	10·2	23·65	53	70



PORTION OF COPPER-ZINC-TIN TERNARY DIAGRAM.

THE AUTHOR'S EXPERIMENTS.

As already indicated, scarcity of material was one of the difficulties with which the author was faced. The ingots made, therefore, were small. They consisted of slabs cast vertically, and the test-pieces were all taken from the bottom, thus obviating the danger of the test-piece being affected by "piping." The dimensions of the slabs were ¾ in. thick by 4 in. long by 3 in. deep. It is clear that, in an iron chill-mould, the rate of cooling of such a thin section would be very rapid. So potent is this fact or of rate of cooling that the risk of the influence of the added elements being obscured was great.

Therefore, a second series of alloys was made, each alloy in this series being cast into a pair of exactly similar ingots, one of which provided a test-piece as cast, whilst the other provided a test-piece which was annealed at 700 deg. C. for one hour, these conditions being similar to those recommended by Primrose. The longer time was allowed owing to the drastically chilling conditions under which the castings were produced. This chilling was more drastic than in the case of the first series. The results are given in the accompanying Tables V and VI.

Owing to the small quantities of metal employed, no attempt was made to determine the temperature, but every care was taken to pour the metal at approximately similar temperatures. There was no case of the metal being poured at a dangerously high nor at a dangerously low temperature.

The percentage of zinc may be obtained by adding together the percentages of copper, tin, and impurity, and subtracting the total from 100.

The main features of interest in the results given in Tables V. and VI are as follow:—

1. They represent exploratory work, undertaken with the object of ascertaining which element or elements showed promise of utility in the manufacture of gun-metal castings, which exercised a benevolent neutrality, and which were actually detrimental.

2. From the point of view of mechanical properties, the results given by arsenic and antimony are not in accord with the views of the metallurgists as mentioned in the Note.

3. Nickel has a decidedly beneficial effect in Series I, whilst in Series II a remarkable increase in ductility is obtained.

4. Lead does not appear seriously to affect the mechanical properites, although it is possible the resistance to shock is lessened.

5. Iron has a beneficial influence on mechanical properties, yield point, tensile stress, and elongation all being raised. Its effect on pouring qualities is bad, but much improvement is effected in this respect by the addition of a trace of aluminium.

6. The influence of manganese is bad in every way, the mechanical properties being adversely affected and the pouring qualities also. The surfaces of the castings were bad.

7. The annealing treatment goes far towards eliminating ill-effects produced by undesirable additions, notably aluminium and silicon. The general improvement brought about by annealing is remarkable.

The test results in Table VII show how very important it is, for the purposes of strict comparison, always to cut the test-piece from the same section of the ingot. From ingot section 1 (Fig. 2) the results are far superior to those from section 2, the next section higher up, yet still far removed from "piping" effects.

A noteworthy feature is that the inferiority of section 2 is not nearly so marked in ingot E, containing nickel, as in the other ingots. Thus nickel seems to confer a double advantage:—

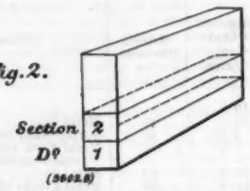
TABLE VII.—*Alloys as Cast.*

Mark.	Composition.				Ingot Section Number.	Yield-Point. Tons per Sq. In.	Ultimate Tensile Stress. Tons per Sq. In.	Elongation per Cent. $= 4\sqrt{\text{area}}$.
	Copper per Cent.	Tin per Cent.	Zinc per Cent.	Impurity per Cent.				
S	88·0	10·0	2·0	nil	1	11·22	23·20	18·0
S	88·0	10·0	2·0	nil	2	10·94	18·47	7·8
A	87 0	10·0	2·0	0·9 As	1	11 6	23·6	15·5
A	87·0	10·0	2 0	0·9 As	2	11·3	19·55	4·75
B	87·0	10·0	2·0	1·0 Al	1	12·75	22·65	9·55
B	87·0	10·0	2·0	1·0 Al	2	13·05	19·7	4·75
C	87·0	10·0	2·0	1·0 Sb	1	11·12	23·15	28·5
C	87·0	10·0	2·0	1·0 Sb	2	11·12	17 7	9·5
E	87·0	10·0	2·0	1·0 Ni	1	12·25	25·02	24·8
E	87·0	10·0	2·0	1·0 Ni	2	11·3	23·6	20·0

1. Improves the mechanical properties of cast and annealed specimens.

2. The improvement extends to a greater proportion of ingot than in any other case.

Fig. 2.



Expressing the losses of mechanical values in section 2 as percentages of the values for section 1, the advantage conferred by nickel is strongly emphasised.

TABLE VIII.

Mark on Ingot.	Impurity.	Percentage Loss. Yield	Percentage Loss. Tensile Strength.	Percentage Loss. Elongation.
S	Nil ..	−3·8	−17·2	−56·7
A	Arsenic ..	−2·6	−17·0	−69·5
B	Aluminium	+2·35 gain	−13·0	−50·0
C	Antimony	nil	−23·3	−66·7
E	Nickel ..	−7·7	− 5·6	−19·3

Tentatively the following are the chief results which may be expected from using the additions with which the author has experimented.

TABLE IX.

Impurity (not exceeding 1 per Cent.).	Effect on Mechanical Properties.	Effect on Fluidity and Surface Appearance of Chill Castings.
Aluminium .. Silicon ..	Hardening and embrittling	Good.
Manganese ..	Inappreciable	Bad.
Arsenic ..	Inappreciable	Good.
Antimony ..	Inappreciable	Inappreciable.
Iron	Strengthening, without loss of ductility.	Bad.
Nickel ..	Toughening; increase of ductility	Inappreciable.

The author would express his thanks to the staff of the Metallurgy Department of the Birmingham Central Technical School, particularly to Messrs. A. Thomas and W. N. Smirles, for their help, respectively in making the alloys and in carrying out the analyses.

A NEW HEAT-INSULATING MATERIAL.—We read in the *Scientific American* that a new heat-insulating material, composed of a mixture of special clay and cork, has been discovered by a Norwegian engineer. The clay and cork mixture is burnt, and the result is the formation of a very light substance, that is said to be eminently suitable for all heat-insulating purposes.

THE INSTITUTION OF AUTOMOBILE ENGINEERS.—The first meeting of the session of the Institution of Automobile Engineers will be held on Wednesday, October 2, at the Royal Society of Arts, John-street, Adelphi, W.C., at 7.30 p.m., when Mr. A. A. Remington will deliver his presidential address. Cards of invitation to the meeting may be obtained on application to the Secretary of the Institution, 28, Victoria-street, S.W. 1.

CHLORINE AND CHLORINE COMPOUNDS.—An Order, dated September 6, has been issued by the Ministry of Munitions, which prohibits, as from September 16, except under licence: (1) The production of chlorine or chlorine compounds in quantities exceeding 1 ton per month; (2) the use by any producer of chlorine or chlorine compounds of more than 1 ton of the same during any month for the purpose of any other trade or business carried on by him; (3) the supply of chlorine or chlorine compounds to any person in quantities exceeding 56 lb. per month, whether under an existing contract or otherwise. The Order also fixes maximum prices of 6d. per pound for liquid chlorine and 15l. per ton for bleaching powder for all sales and purchases effected after September 6. These prices are net cash prices for liquid chlorine and bleaching powder delivered f.o.r. maker's works and include the cost of filling into packages (cylinders and casks), but not the cost of the packages themselves. All persons holding a stock of 1,000 lb. or upwards of chlorine and chlorine compounds on October 1, 1918, are required to make returns of their stocks within 14 days from that date. Such returns, as well as applications for licences, should be addressed to the Department of Explosives Supply (Ministry of Munitions), Storey's Gate, Westminster, S.W. 1, and marked "Chlorine Control." For the purposes of the Order chlorine means elementary chlorine, either in gaseous or liquid form, and chlorine compound means bleaching powder, sodium hypochlorite, all descriptions of chlorine bleach liquor and all other compounds of or products containing chlorine which are commonly manufactured direct from chlorine. Hydrochloric acid is not affected by this Order.

ON RAPID METHOD OF ESTIMATING PHOSPHORUS IN BRONZES.*

By T. E. ROONEY, A.M.S.T., Member (The National Physical Laboratory).

BRONZE drillings, to the amount of from 0.5 grammes to 2 grammes, are dissolved in a mixture of 20 c.c. strong nitric acid and 10 c.c. strong hyrdochloric acid, or, if preferred, 60 c.c. nitric acid (specific gravity, 1.135) and 10 c.c. hydrochloric acid. The mixture is digested for some time without boiling until most of the red fumes have been evolved. If the concentrated acids are used the mixture is then diluted to about 70 c.c. The liquid is next cooled and 40 c.c. of ammonia (specific gravity, 0.96) added slowly with constant shaking, followed by 35 c.c. of nitromolybdate solution, and the whole shaken well for a few minutes. The mixture is allowed to stand for one to two hours until the precipitate has settled out, when it is filtered, preferably on pulp, washed with water until free from acid, the filter and precipitate transferred back into the flask, excess of N/20 caustic soda run in from a burette, the whole well mixed and the excess of caustic soda titrated with N/20 sulphuric acid, using phenolphthalein as an indicator.

1 c.c. N/20 caustic soda = 0.00337 per cent. P on 2 grammes.

The method is based on the well-known volumetric method of estimating phosphorus in steel. It is best carried out in a 600 c.c. conical flask and a rubber stopper used in the final shaking.

POINTS.

1. The digestion with acid must be long enough to oxidize all the phosphorus, or results will be low.

2. Boiling or heating must not be too prolonged or tin will be precipitated and will be difficult to re-dissolve.

A comparison of the method has been made with a gravimetric method, in which the tin oxide containing the phosphorus is mixed with Hepar mixture and fused. The resulting melt is dissolved in hot water, the solution acidified with a little hydrochloric acid whereby the tin is precipitated.

The tin sulphide is allowed to settle, and is then filtered off, the filtrate being boiled to remove sulphuretted hydrogen; nitric acid is added and taken down to low bulk, and the phosphorus precipitated and estimated as magnesium pyrophosphate in the usual way.

The results obtained by the two methods on a number of commercial bronzes are given in the accompanying table, along with the approximate composition of the bronzes.

Table showing Results obtained with different Samples of Commercial Bronzes by Rapid and Gravimetric Methods of Analysis.

Copper.	Tin.	Lead.	Zinc.	Iron.	Phosphorus.	
					Gravimetric.	Volumetric.
88·32	2·56	8·08	0·11	0·24	0·45	0·42
88·30	2·59	8·06	0·11	0·24	0·39	0·41
88·59	10·63	—	0·06	—	0·80	0·81
88·57	10·65	0·02	0·14	—	1·43	1·40
88·92	10·00	—	0·18	—	0·76	0·74
77·31	10·30	10·45	0·10	—	1·45	1·44
88·95	2·07	8·24	0·16	—	0·44	0·42
93·73	6·07	—	—	—	0·17	0·18
89·60	2·41	7·76	—	—	0·39	0·37
88·59	10·14	—	—	—	1·24	1·22
88·58	10·37	0·06	0·88	—	0·011	0·010
78·05	8·76	12·48	0·24	—	0·43	0·44

The author wishes to express his thanks to Sir Richard T. Glazebrook, C.B., F.R.S., Director of the National Physical Laboratory, for permission to publish this Note and to Mr. P. G. Ward, B.Sc., for assistance received.

ELECTRIC RESISTANCE OF PORCELAIN AND MAGNESIA.—All insulators fail more or less at high temperatures, and porcelain spark plugs show noticeable current leakage at 1,000 deg. C. Mr. P. H. Brace described some new experiments on the resistivity of magnesite and porcelain before the May meeting of the American Electrochemical Society. He tried magnesite, of 94 per cent. of MgO in two forms, in test blocks of 1 in. by 0·8 in. The magnesite was either used after electrical fusion, or it was fused, then crushed to powder, moulded under heavy pressure, and baked at 1,700 deg. The test pieces were placed between nickel grids and loaded with 11 lb., layers of asbestos being applied on the outside of the grids; the specimens were heated up to 1,000 deg. C. cooled quickly, and reheated to various temperatures during the resistivity tests with continuous currents of 120 volts or alternating currents. The resistivity appeared to be a function of the time during which the current was applied; the final resistance observed was greater, several times greater frequently, than the original resistance. This change was greater with magnesite than with porcelain, and magnesite had a higher resistance than porcelain at the same temperature. The moulded magnesite gave on the whole lower resistance values than the merely fused material, possibly because the grinding had introduced small impurities. In all cases some evidence of electrolysis was obtained, the resistance first falling and then rising again on reversing the current. This was particularly noticeable in hot porcelain at 910 deg. and 990 deg. C.; porcelain in fact, behaved like an accumulator, giving for half an hour or so a counter electromotive force of 0·7 volt.

* Note submitted to the Institute of Metals, Wednesday, September 11, 1918.

IMPORTS AND EXPORTS.

THE returns have now been published for August of this year. A month ago we dealt with the tendencies of oversea trade in special items such as steel ingots, blooms, &c., steel sections, wrought-iron sections and plates of iron or steel over ¼ in. thick. The general result was to indicate that we were increasingly able to supply our own needs in spite of heavy falls in importations, and to send large consignments to our Allies. These tendencies are substantially maintained, and there is, therefore, no need to repeat the figures which are not greatly different. Steel ingots, billets and sections are being imported in smaller quantities, while the exports are also less. The heaviest fall during August is in the export of steel sections. There is also a heavy fall in the export of steel billets, &c., as compared with 1917, but, as the total of this item is still above the total of 1916, we can only assume that the great rise in this export in 1917 was due to the pressing needs of France or Italy. Perhaps the burden has been more fully shared by the United States, since neither France nor Italy can have produced much.

It is instructive to compare the total figures, including many other heavy items than those just mentioned, of iron and steel materials. The main additional items are imported pig-iron, tubes and wire, and exported pig-iron, wire, plates, castings and railway material. All iron and steel, but not machinery, are included in the following table. The years 1910 and 1913 are added to show the pre-war tendency of trade and give a standard by which the war effects may be measured.

Manufactured Iron and Steel Materials.

Eight Months.	Imports. Tons.	Exports. Tons.
1910	859,793	3,053,652
1913	1,436,794	3,338,302
1914	1,428,114	2,954,263
1915	766,319	2,087,676
1916	551,021	2,452,854
1917	317,436	1,706,075
1918	181,872	1,129,050

These figures are worth careful attention. They indicate a fairly steady tendency in the same direction in each column. A more remarkable result, however, is that if we regard net exports as the difference between imports and exports, the result is a much steadier net export. This result may be tabulated thus in rough proportions the years compared being 1913 and 1918:—

Ratio of fall in imports ...	100 to 14
Ratio of fall in exports ...	100 to 34
Ratio of fall in net exports ...	100 to 56

Usually, this comparison could not be made because in normal trade there is a great difference of form in the articles imported and exported. When we consider, however, that all articles in both columns originate immediately from the same material and that the forms produced have been intentionally altered the comparison is quite allowable, and very instructive. It shows the diversion of production from the purposes of commerce to those of national defence.

A month ago we also gave figures of special kinds of machinery and the changes in tendency are too slight to warrant repeating the figures. We may, however, consider the totals of this class.

Machinery and Parts Thereof.

Eight Months.	Imports. Tons.	Exports. Tons.
1910	45,615	433,602
1913	72,552	494,917
1914	73,556	476,731
1915	61,358	229,109
1916	52,966	215,318
1917	45,937	192,264
1918	56,123	131,397

This classification includes as machinery: engines, electrical machines (not apparatus or instruments, cables, &c.), and agricultural, mining, sewing and textile machines, steam boilers and a large "unenumerated" class. Marine engines and boilers fitted to ships and Motor car and aircraft engines, whether loose or fitted, are not included.

Here a comparison cannot be made on similar lines, because the classification of machinery and parts is on a basis that is technically absurd. For instance, sewing machines and typewriters are classed as machinery; and though their weight in tons is small it is stated. Motor cars, motor bicycles, bicycles, railway wagons and airplanes are not classed as machinery and weights, though very considerable, are not given. All these classifications include "parts thereof," so that motor car and airplane engines may be imported and exported in thousands of tons, but cannot be identified as machinery.

The total figures of machinery show a very small variation in imports, and an inconstant tendency in that variation. Exports, however, have fallen heavily and continually.

It must be borne in mind that the immense masses of iron and steel war supplies for our own armies and Navy are not included in these returns.

CONCRETE VESSELS IN COLLISION.—The only actual instance on record at present of a collision of two concrete vessels, says *Ferro-Concrete*, is one furnished last year during the flooding of a dock basin at Balboa, on the Panama Canal. It is recorded that after the blowing-up of the coffer-dam used in constructing the basin, a powerful current was established, breaking from their moorings two concrete pontoons, 120 ft. long by 28 ft. beam, which circled about the basin and collided violently, but without suffering any damage.